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THE

HISTORY

AND

PRESENT STATE

OF

ELECTRICITY,

WITH

ORIGINAL EXPERIMENTS,

By JOSEPH PRIESTLEY, LL.D. F.R.S.

THE THIRD EDITION,

CORRECTED AND ENLARGED.

Causa latet, vis est notissima. OVID.

VOL. I.

LONDON,

Printed for C. BATHURST, and T. LOWNDES, in Fleet-Street; J. RIVINGTON, and J. JOHNSON, in St. Paul's Church-Yard; S. CROWDER, G. ROBINSON, and R. BALDWIN, in Pater-noster Row; T. BECKET, and T. CADELL, in the Strand.

MDCCLXXV.

TO

THE RIGHT HONOURABLE

JAMES Earl of MORTON,

PRESIDENT OF THE ROYAL SOCIETY,

This HISTORY, &c.

IS,

WITH THE GREATEST RESPECT

INSCRIBED

By his LORDSHIP's

MOST OBEDIENT,

AND MOST HUMBLE

SERVANT,

JOSEPH PRIESTLEY.

THE PREFACE TO THE FIRST EDITION.

IN writing the *History and Present State of Electricity*, I flatter myself that I shall give pleasure, as well to persons who have a taste for Natural Philosophy in general, as to electricians in particular; and I hope the work will be of some advantage to the science itself. Both these ends would certainly be answered in a considerable degree, were the execution at all answerable to the design.

THE History of Electricity is a field full of pleasing objects, according to all the genuine and universal principles of taste, deduced from a knowledge of human nature. Scenes like these, in which we see a gradual rise and progress in things, always exhibit a pleasing spectacle to the human mind. Nature, in all her delightful walks, abounds with such views, and they are in a more especial manner connected with every thing that relates to human life and happiness; things, in their own nature, the most interesting to us. Hence it is, that the power of association has annexed crouds of pleasing sensations to the contemplation of every object, in which this property is apparent.

This pleasure, likewise, bears a considerable resemblance to that of the sublime, which is one of the most exquisite of all those that affect the human imagination. For an object in which we see a perpetual progress and improvement is, as it were, continually rising in its magnitude; and moreover, when we see an actual increase, in a long period of time past, we cannot help forming an idea of an unlimited increase in futurity; which is a prospect really boundless, and sublime.

The pleasures arising from views exhibited in *civil*, *natural*, and *philosophical* history, are, in certain respects, different from one another. Each has its advantages, and each its defects: and both their advantages and defects contribute to adapt them to different classes of readers.

Civil history presents us with views of the strongest passions and sentiments of the human mind, into which every man can easily and perfectly enter, and with such incidents, respecting happiness and misery, as we cannot help feeling, would alarm and affect us in a very sensible manner; and therefore, we are at present alarmed and affected by them to a considerable degree. Hence the pleasure we receive from civil history arises, chiefly from the exercise it affords our passions. The imagination is only entertained with scenes which occasionally start up, like interludes, or episodes, in the great drama, to which we are principally attentive. We are presented, indeed, with the prospect of gradual

gradual improvement during the riſe of great empires; but, as we read on, we are oblig-ed to contemplate the diſagreeable reverſe. And the hiſtory of moſt ſtates preſents nothing but a tedious uniformity, without any ſtrik-ing events, to diverſify and embelliſh the proſpect. Beſides, if a man have any ſenti-ment of virtue and benevolence, he cannot help being ſhocked with a view of the vices and miſeries of mankind; which, though they be not all, are certainly the moſt glar-ing and ſtriking objects in the hiſtory of hu-man affairs. An attention, indeed, to the conduct of divine Providence, which is ever bringing good out of evil, and gradually conducting things to a more perfect and glo-rious ſtate, tends to throw a more agreeable light on the more gloomy parts of hiſtory; but it requires great ſtrength of mind to comprehend thoſe views; and, after all, the feelings of the heart too often overpower the concluſions of the head.

NATURAL hiſtory exhibits a boundleſs variety of ſcenes, and yet infinitely ana-logous to one another. A naturaliſt has, conſequently, all the pleaſure which the con-templation of uniformity and variety can give the mind; and this is one of the moſt copious ſources of our intellectual pleaſures. He is likewiſe entertained with a proſpect of gradual improvement, while he ſees every object in nature riſing by due degrees to its maturity and perfection. And while new plants, new animals, and new foſſils are per-

petually pouring in upon him, the moſt pleaſing views of the unbounded power, wiſdom, and goodneſs of God are conſtantly preſent to his mind. But he has no direct view of human ſentiments and human actions; which, by means of their endleſs aſſociations, greatly heighten and improve all the pleaſures of taſte.

The hiſtory of philoſophy enjoys, in ſome meaſure, the advantages both of civil and natural hiſtory, whereby it is relieved from what is moſt tedious and diſguſting in both. Philoſophy exhibits the powers of nature, diſcovered and directed by human art. It has, therefore, in ſome meaſure, the boundleſs variety with the amazing uniformity of the one, and likewiſe every thing that is pleaſing and intereſting in the other. And the idea of continual riſe and improvement is conſpicuous in the whole ſtudy, whether we be attentive to the part which nature, or that which men are acting in the great ſcene.

It is here that we ſee the human underſtanding to its greateſt advantage, graſping at the nobleſt objects, and increaſing its own powers, by acquiring to itſelf the powers of nature, and directing them to the accompliſhment of its own views; whereby the ſecurity, and happineſs of mankind are daily improved. Human abilities are chiefly conſpicuous in adapting means to ends, and in deducing one thing from another by the method of analogy; and where ſhall we find inſtances of greater ſagacity, than in philo-

ſophers

ſophers diverſifying the ſituations of things, in order to give them an opportunity of ſhowing their mutual relations, affections, and influences; deducing one truth and one diſcovery from another, and applying them all to the uſeful purpoſes of human life.

If the exertion of human abilities, which cannot but form a delightful ſpectacle for the human imagination, give us pleaſure, we enjoy it here in a higher degree than while we are contemplating the ſchemes of warriors, and the ſtratagems of their bloody art. Beſides, the object of philoſophical purſuits throws a pleaſing idea upon the ſcenes they exhibit; whereas a reflection upon the real objects and views of moſt ſtateſmen and conquerors cannot but take from the pleaſure, which the idea of their ſagacity, foreſight, and comprehenſion would otherwiſe give to the virtuous and benevolent mind. Laſtly, the inveſtigation of the powers of nature, like the ſtudy of Natural Hiſtory, is perpetually ſuggeſting to us views of the divine perfections and providence, which are both pleaſing to the imagination, and improving to the heart.

But though other kinds of hiſtory may, in ſome reſpects, vie with that of philoſophy, nothing that comes under the denomination of hiſtory can exhibit inſtances of ſo fine a riſe and improvement in things, as we ſee in the progreſs of the human mind, in philoſophical inveſtigations. To whatever height we have arrived in natural ſcience, our be-

ginnings were very low, and our advances have been exceedingly gradual. And to look down from the eminence, and to see, and compare all those gradual advances in the ascent, cannot but give the greatest pleasure to those who are seated on the eminence, and who feel all the advantages of their elevated situation. And considering that we ourselves are, by no means, at the top of human scienee; that the mountain still ascends beyond our sight, and that we are, in fact, not much above the foot of it, a view of the manner in which the ascent has been made, cannot but animate us in our attempts to advance still higher, and suggest methods and expedients to assist us in our farther progress.

GREAT conquerors, we read, have been both animated, and also, in a great measure, formed by reading the exploits of former conquerors. Why may not the same effect be expected from the history of philosophy to philosophers? May not even more be expected in this case? The wars of many of those conquerors, who received this advantage from history, had no proper connection with former wars: they were only analogous to them. Whereas the whole business of philosophy, diversified as it is, is but one; it being one and the same great scheme, that all philosophers, of all ages and nations, have been conducting, from the beginning of the world; so that the work being the same, the labours of one are not only analogous to those of

of another, but in an immediate manner subservient to them; and one philosopher succeeds another in the same field; as one Roman proconsul succeeded another in carrying on the same war, and pursuing the same conquests, in the same country. In this case, an intimate knowledge of what has been done before us cannot but greatly facilitate our future progress, if it be not absolutely necessary to it.

These histories are evidently much more necessary in an advanced state of science, than in the infancy of it. At present philosophical discoveries are so many, and the accounts of them are so dispersed, that it is not in the power of any man to come at the knowledge of all that has been done, as a foundation for his own inquiries. And this circumstance appears to me to have very much retarded the progress of discoveries.

Not that I think philosophical discoveries are now at a stand. On the other hand, as quick advances seem to have been made of late years, as in any equal period of time past whatever. Nay, it appears to me, that the progress is really accelerated. But the increase of knowledge is like the increase of a city. The building of some of the first streets makes a great figure, is much talked of, and known to every body; whereas the addition of, perhaps, twice as much building, after it has been swelled to a considerable size, is not so much as taken notice of,

and may be really unknown to many of the inhabitants. If the additions which have been made to the buildings of the city of London, in any ſingle year of late, had been made two or three centuries ago, it could not have eſcaped the obſervation of hiſtorians; whereas, now, they are ſo ſcattered, and the proportion they bear to the whole city is ſo ſmall, that they are hardly noticed. For the ſame reaſon, the improvements that boys make at ſchool, or that young gentlemen make at an academy, or the univerſity, are more taken notice of than all the knowledge they acquire afterwards, though they continue their ſtudies with the ſame aſſiduity and ſucceſs.

The hiſtory of experimental philoſophy, in the manner in which it ought to be written, to be of much uſe, would be an immenſe work; but it were much to be wiſhed, that perſons who have leiſure, and ſufficient abilities, would undertake it in ſeparate parts. I have executed it, in the beſt manner I have been able, for that branch which has been my own favourite amuſement; and I ſhall think myſelf happy, if the attempt excite other perſons to do the like for theirs.

I cannot help thinking myſelf to have been peculiarly fortunate, in undertaking the hiſtory of electricity, at the moſt proper time for writing it, when the materials were neither too few, nor too many to make a hiſtory; and when they were ſo ſcattered, as

to

to make the undertaking highly desirable, and the work peculiarly useful to Englishmen.

I LIKEWISE think myself exceedingly happy in my subject itself. Few branches of Natural Philosophy would, I think, make so good a subject for a history. Few can boast such a number of discoveries, disposed in so fine a series, all comprised in so short a space of time, and all so recent, the principal actors in the scene being still living.

WITH several of these principal actors it has been my singular honour and happiness to be acquainted; and it was their approbation of my plan, and their generous encouragement that induced me to undertake the work. With gratitude I acknowledge my obligations to Dr. Watson, Dr. Franklin, and Mr. Canton, for the books, and other materials with which they have supplied me, and for the readiness with which they have given me any information in their power to procure. In a more especial manner am I obliged to Mr. Canton, for those original communications of his, which will be found in this work, and which cannot fail to give a value to it, in the esteem of all the lovers of electricity. My grateful acknowledgements are also due to the Rev. Dr. Price, F R.S. and to the Rev. Mr. Holt, our professor of Natural Philosophy at Warrington, for the attention they have given to the work, and for the many important services they have rendered me with respect to it.

To

To the gentlemen above mentioned the public is, likewiſe, indebted for whatever they may think of value in the *original experiments* which I have related of my own. It was from converſing with them that I was firſt led to entertain the thought of attempting any thing new in this way, and it was their example, and favourable attention to my experiments, that animated me in the purſuit of them. In ſhort, without them, neither my experiments, nor this work would have had any exiſtence.

The hiſtorical part of this work, the reader, I hope will find to be full and circumſtantial, and at the ſame ſuccinct. Every new fact, or important circumſtance. I have noted as it aroſe; but I have abridged all long details, and have carefully avoided all digreſſions and repetitions. For this purpoſe, I have peruſed every original author, to which I could have recourſe; and every quotation in the margin points to the authority that I myſelf conſulted, and from which the account in the text was actually taken. Where I could not procure the original authors, I was obliged to quote them at ſecond hand, but the reference will always ſhow where that has been done. That I might not miſrepreſent any writer, I have generally given the reader his own words, or the plaineſt tranſlation I could make of them; and this I have done, not only in direct quotations, but where, by a change of perſon, I have made the language my own.

I MADE

I MADE it a rule to myſelf, and I think I have conſtantly adhered to it, to take no notice of the miſtakes, miſapprehenſions, and altercations of electricians; except ſo far as, I apprehended, a knowledge of them might be uſeful to their ſucceſſors. All the diſputes which have no way contributed to the diſcovery of truth, I would gladly conſign to eternal oblivion. Did it depend upon me, it ſhould never be known to poſterity, that there had ever been any ſuch thing as envy, jealouſy, or cavilling among the admirers of my favourite ſtudy. I have, as far as my beſt judgment could direct me, been juſt to the merits of all perſons concerned. If any have made unjuſt claims, by arrogating to themſelves the diſcoveries of others, I have ſilently reſtored them to the right owner, and generally without ſo much as giving a hint that any injuſtice had ever been committed. If I have, in any caſe, given a hint, I hope it will be thought, by the offending parties themſelves, to be a very gentle one; and that it will be a *memento*, which will not be without its uſe.

I THINK I have kept clear of any mean partiality towards my own countrymen, and even my own acquaintance. If Engliſh authors are oftener quoted than foreign, it is becauſe they were more eaſily procured; and I have found a difficulty I could not have expected, in procuring foreign publications upon this ſubject.

I FIND

I FIND it impoſſible to write a preface to this work, without diſcovering a little of the enthuſiaſm which I have contracted from an attention to it, by expreſſing my wiſhes, that more perſons, of a ſtudious and retired life, would admit this part of experimental philoſophy into their ſtudies. They would find it agreeably to diverſify a courſe of ſtudy, by mixing ſomething of action with ſpeculation, and giving ſome employment to the hands and arms, as well as to the head. Electrical experiments are, of all others, the cleaneſt, and the moſt elegant, that the compaſs of philoſophy exhibits. They are performed with the leaſt trouble, there is an amazing variety in them, they furniſh the moſt pleaſing and ſurpriſing appearances for the entertainment of one's friends, and the expence of inſtruments may well be ſupplied, by a proportionable deduction from the purchaſe of books, which are generally read and laid aſide, without yielding half the entertainment.

THE inſtruction we are able to get from books is, comparatively, ſoon exhauſted; but philoſophical inſtruments are an endleſs fund of knowledge. By philoſophical inſtruments, however, I do not here mean the globes, the orrery, and others, which are only the means which ingenious men have hit upon, to explain their own conceptions of things to others; and which, therefore, like books, have no uſes more extenſive than the views

views of human ingenuity; but ſuch as the air-pump, condenſing engine, pyrometer, &c. (with which electrical machines are to be ranked) and which exhibit the operations of nature, that is of the God of nature himſelf, which are infinitely various. By the help of theſe machines, we are able to put an endleſs variety of things into an endleſs variety of ſituations, while nature herſelf is the agent that ſhows the reſult. Hereby the laws of her action are obſerved, and the moſt important diſcoveries may be made; ſuch as thoſe who firſt contrived the inſtrument could have no idea of.

In electricity, in particular, there is the greateſt room to make new diſcoveries. It is a field but juſt opened, and requires no great ſtock of particular preparatory knowledge: ſo that any perſon who is tolerably well verſed in experimental philoſophy, may preſently be upon a level with the moſt experienced electricians. Nay, this hiſtory ſhows, that ſeveral raw adventurers have made themſelves as conſiderable, as ſome who have been, in other reſpects, the greateſt philoſophers. I need not tell my reader of how great weight this conſideration is, to induce him to provide himſelf with an electrical apparatus. The pleaſure ariſing from the moſt trifling diſcoveries of one's own, far exceeds what we receive from underſtanding the much more important diſcoveries of others; and a mere reader has no chance of finding new truths, in compariſon of him who now and then

amuſes

amuſes himſelf with philoſophical experiments.

HUMAN happineſs depends chiefly upon having ſome object to purſue, and upon the vigour with which our faculties are exerted in the purſuit. And, certainly, we muſt be much more intereſted in purſuits wholly our own, than when we are merely following the track of others. Beſides, this pleaſure has reinforcements from a variety of ſources, which I ſhall not here undertake to trace; but which contribute to heighten the ſenſation, far beyond any thing elſe of this kind that can be experienced by a perſon of a ſpeculative turn of mind.

IT is a great recommendation of the ſtudy of electricity, that it now appears to be, by no means, a ſmall object. The electric fluid is no local, or occaſional agent in the theatre of the world. Late diſcoveries ſhow that its preſence and effects are every where, and that it acts a principal part in the grandeſt and moſt intereſting ſcenes of nature. It is not, like magnetiſm, confined to one kind of bodies, but every thing we know is a conductor or non-conductor of electricity. Theſe are properties as eſſential and important as any they are poſſeſſed of, and can hardly fail to ſhow themſelves wherever the bodies are concerned.

HITHERTO philoſophy has been chiefly converſant about the more ſenſible properties of bodies; electricity, together with chymiſtry, and the doctrine of light and colours, ſeems

ſeems to be giving us an inlet into their internal ſtructure, on which all their ſenſible properties depend. By purſuing this new light, therefore, the bounds of natural ſcience may poſſibly be extended, beyond what we can now form an idea of. New worlds may open to our view, and the glory of the great Sir Iſaac Newton himſelf, and all his contemporaries, be eclipſed, by a new ſet of philoſophers, in quite a new field of ſpeculation. Could that great man reviſit the earth, and view the experiments of the preſent race of electricians, he would be no leſs amazed than Roger Bacon, or Sir Francis, would have been at his. The electric ſhock itſelf, if it be conſidered attentively, will appear almoſt as ſurpriſing as any diſcovery that he made; and the man who could have made that diſcovery, by any reaſoning *a priori*, would have been reckoned a moſt extraordinary genius: but electrical diſcoveries have been made ſo much by accident, that it is more the powers of nature, than of human genius, that excite our wonder with reſpect to them. But if the ſimple electric ſhock would have appeared ſo extraordinary to Sir Iſaac Newton, what would he have ſaid upon ſeeing the effects of a modern electrical battery, and an apparatus for drawing lightning from the clouds! What inexpreſſible pleaſure would it give a modern electrician, were the thing poſſible, to entertain ſuch a man as Sir Iſaac for a few hours with his principal experiments!

To

To return from this excurſion to the buſineſs of a preface: beſides relating the hiſtory of electrical diſcoveries, in the order in which they were made, I thought it neceſſary, in order to make the work more uſeful, eſpecially to young electricians, to ſubjoin a methodical treatiſe on the ſubject, containing the ſubſtance of the hiſtory in another form, with obſervations and inſtructions of my own. The particular uſes of theſe parts of the work are expreſſed at large in the introductions to them. And, in the laſt place, I have given an account of ſuch original experiments as I have been ſo fortunate as to hit upon myſelf.

I INTITLE the work the *Hiſtory and Preſent State of Electricity*; and whether there be any more additions of the whole work or not, care will be taken to preſerve the propriety of the title, by occaſionally printing ADDITIONS, in the ſame ſize, as new diſcoveries are made; which will always be ſold at a reaſonable price to the purchaſers of the book; or given *gratis*, if the bulk be inconſiderable.

CONSIDERING what reſpectable perſons have already honoured this work with their valuable communications, I hope it will not be deemed arrogance in me, if I here advertiſe, that if any perſon ſhall make diſcoveries in electricity, which he would chuſe to ſee recorded in this hiſtory, he will oblige me by a communication of them; and if they be really original, a proper place ſhall cer-

certainly be assigned to them in the next edition, or paper of additions. And I hope that, if electricians in general would fall into this method, and make either a periodical, or occasional, but joint communication of their discoveries to the public, the greatest advantage would thence accrue to the science.

The business of philosophy is so multiplied, that all the books of general philosophical transactions cannot be purchased by many persons, or read by any person. It is high time to *subdivide* the business, that every man may have an opportunity of seeing every thing that relates to his own favourite pursuit; and all the various branches of philosophy would find their account in this amicable separation. Thus the numerous branches of a large overgrown family, in the patriarchal ages, found it necessary to separate; and the convenience of the whole, and the strength, and increase of each branch were promoted by the separation. Let the youngest daughter of the science set the example to the rest, and show that she thinks herself considerable enough to make her appearance in the world without the company of her sisters.

But before this general separation, let each collect together every thing that belongs to her, and march off with her whole stock. To drop the allusion: let histories be written of all that has been done in every particular branch of science, and let the whole be seen

at one view. And when once the entire progreſs, and preſent ſtate of every ſcience ſhall be fully and fairly exhibited, I doubt not but we ſhall ſee a new and capital *æra* commence in the hiſtory of all the ſciences. Such an eaſy, full, and comprehenſive view of what has been done hitherto could not fail to give new life to philoſophical inquiries. It would ſuggeſt an infinity of new experiments, and would undoubtedly greatly accelerate the progreſs of knowledge; which is at preſent retarded, as it were, by its own weight, and the mutal entanglement of its ſeveral parts.

I WILL juſt throw out a farther hint, of what, I think, might be favourable to the increaſe of philoſophical knowledge. At preſent there are, in different countries in Europe, large incorporate ſocieties, with funds for promoting philoſophical knowledge in general. Let philoſophers now begin to ſubdivide themſelves, and enter into ſmaller combinations. Let the ſeveral companies make ſmall funds, and appoint a director of experiments. Let every member have a right to appoint the trial of experiments in ſome proportion to the ſum he ſubſcribes, and let a periodical account be publiſhed of the reſult of them all, ſucceſsful or unſucceſsful. In this manner, the powers of all the members would be united and increaſed. Nothing would be left untried, which could be compaſſed at a moderate expence, and it being *one perſon's buſineſs* to attend to theſe experiments, they would be made, and reported without

without loſs of time. Moreover, as all incorporations in theſe ſmaller ſocieties ſhould be avoided, they would be encouraged only in proportion as they were found to be uſeful; and ſucceſs in ſmaller things would excite them to attempt greater.

I by no means diſapprove of large, general, and incorporated ſocieties. They have their peculiar uſes too; but we ſee by experience, that they are apt to grow too large, and their forms are too ſlow for the diſpatch of the *minutiæ* of buſineſs, in the preſent multifarious ſtate of philoſophy. Let recourſe be had to rich incorporated ſocieties, to defray the expence of experiments, to which the funds of ſmaller ſocieties ſhall be unequal. Let their tranſactions contain a ſummary of the more important diſcoveries, collected from the ſmaller periodical publications. Let them, by rewards, and other methods, encourage thoſe who diſtinguiſh themſelves in the inferior ſocieties; and thus give a general attention to the whole buſineſs of philoſophy.

I wish all the incorporated philoſophical ſocieties in Europe would join their funds (and I wiſh they were ſufficient for the purpoſe) to fit out ſhips for the complete diſcovery of the face of the earth, and for many capital experiments which can only be made in ſuch extenſive voyages.

Princes will never do this great buſineſs to any purpoſe. The ſpirit of adventure ſeems to be totally extinct in the preſent race of merchants. This diſcovery is a grand deſide-

ratum in ſcience; and where may this pure and noble enthuſiaſm for ſuch diſcoveries be expected but among philoſophers, men uninfluenced by motives either of policy or gain? Let us think ourſelves happy if princes give no obſtruction to ſuch deſigns. Let them fight for the countries when they are diſcovered, and let merchants ſcramble for the advantage that may be made of them. It will be an acquiſition to philoſophers if the ſeat of war be removed ſo far from the ſeat of ſcience; and freſh room will be given to the exertion of genius in trade, when the old beaten track is deſerted, when the old ſyſtem of traffic is unhinged, and when new and more extenſive plans of commerce take place. I congratulate the preſent race of philoſophers on what is doing by the Engliſh court in this way *; for with whatever view expeditions into the South Seas are made, they cannot but be favourable to philoſophy.

NATURAL PHILOSOPHY is a ſcience which more eſpecially requires the aid of wealth. Many others require nothing but what a man's own reflection may furniſh him with. They who cultivate them find within themſelves every thing they want. But experimental philoſophy is not ſo independent. Nature will not be put out of her way, and ſuffer her materials to be thrown into all that variety of ſituations which philoſophy requires, in order to diſcover her wonderful powers, with-

* Written in the year 1766.

out

out trouble and expence. Hence the patronage of the great is eſſential to the flouriſhing ſtate of this ſcience. Others may project great improvements, but they only have the power of carrying them into execution.

Besides, they are the higher claſſes of men which are moſt intereſted in the extenſion of all kinds of natural knowledge; as they are moſt able to avail themſelves of any diſcoveries, which lead to the felicity and embelliſhment of human life. Almoſt all the elegancies of life are the produce of thoſe polite arts, which could have had no exiſtence without natural ſcience, and which receive daily improvements from the ſame ſource. From the great and the opulent, therefore, theſe ſciences have a natural claim for protection; and it is evidently their intereſt not to ſuffer promiſing inquiries to be ſuſpended for want of the means of proſecuting them.

But other motives, beſides this ſelfiſh one, may reaſonably be ſuppoſed to attach perſons in the higher ranks of life to the ſciences; motives more exalted, and flowing from the moſt extenſive benevolence. From Natural Philoſophy have flowed all thoſe great inventions, by means of which mankind in general are able to ſubſiſt with more eaſe, and in greater numbers upon the face of the earth. Hence ariſe the capital advantages of men above brutes, and of civilization above barbarity. And by theſe ſciences alſo it is, that the views of the human mind itſelf are enlarged, and our common nature improved and ennobled. It is for the honour of the

ſpecies, therefore, that theſe ſciences ſhould be cultivated with the utmoſt attention.

AND of whom may theſe enlarged views, comprehenſive of ſuch great objects, be expected, but of thoſe whom divine providence has raiſed above the reſt of mankind. Being free from moſt of the cares peculiar to individuals, they may embrace the intereſts of the whole ſpecies, feel for the wants of mankind, and be concerned to ſupport the dignity of human nature.

GLADLY would I indulge the hope, that we ſhall ſoon ſee theſe motives operating in a more extenſive manner than they have hitherto done; that by the illuſtrious example of a few, a taſte for natural ſcience will be excited in many, in whom it will operate the moſt effectually to the advantage of ſcience and of the world; and that all kinds of philoſophical inquiries will, henceforward, be conducted with more ſpirit, and with more ſucceſs than ever.

WERE I to purſue this ſubject, it would carry me far beyond the reaſonable bounds of a preface. I ſhall therefore conclude with mentioning that ſentiment, which ought to be uppermoſt in the mind of every philoſopher, whatever be the immediate object of his purſuit; that ſpeculation is only of uſe as it leads to *practice*, that the immediate uſe of natural ſcience is the power it gives us over nature, by means of the knowledge we acquire of its laws; whereby human life is, in its preſent ſtate, made more comfortable and happy; but that the greateſt, and nobleſt uſe

use of philosophical speculation is the discipline of the heart, and the opportunity it affords of inculcating benevolent and pious sentiments upon the mind.

A PHILOSOPHER ought to be something greater, and better than another man. The contemplation of the works of God should give a sublimity to his virtue, should expand his benevolence, extinguish every thing mean, base, and selfish in his nature, give a dignity to all his sentiments, and teach him to aspire to the moral perfections of the great author of all things. What great and exalted beings would philosophers be, would they but let the objects about which they are conversant have their proper moral effect upon their minds! A life spent in the contemplation of the productions of divine power, wisdom, and goodness, would be a life of devotion. The more we see of the wonderful structure of the world, and of the laws of nature, the more clearly do we comprehend their admirable uses, to make all the percipient creation happy: a sentiment, which cannot but fill the heart with unbounded love, gratitude, and joy.

EVEN every thing painful and disagreeable in the world appears to a philosopher, upon a more attentive examination, to be excellently provided, as a remedy of some greater inconvenience, or a necessary means of a much greater happiness; so that, from this elevated point of view, he sees all temporary evils and inconveniences to vanish, in the glorious prospect of the greater good to which they are subservient. Hence he is able to venerate and

rejoice in God, not only in the bright sunshine, but also in the darkest shades of nature, whereas vulgar minds are apt to be disconcerted with the appearance of evil.

Nor is the cultivation of piety useful to us only as *men*, it is even useful to us as *philosophers:* and as true philosophy tends to promote piety, so a generous and manly piety is reciprocally, subservient to the purposes of philosophy; and this both in a direct and indirect manner. While we keep in view the great final cause of all the parts and the laws of nature, we have some clue, by which to trace the efficient cause. This is most of all obvious in that part of philosophy which respects the animal creation. As the great and excellent Dr. Hartley observes. "Since this world is a "system of benevolence, and consequently its "author the object of unbounded love and a-"doration, benevolence and piety are our on-"ly true guides in our inquiries into it; the "only keys which will unlock the mysteries "of nature, and clues which lead through her "labyrinths. Of this all branches of natural "history, and natural philosophy afford abun-"dant instances. In all these inquiries, let the "inquirer take it for granted previously, that "every thing is right, and the best that can be "*ceteris manentibus*; that is, let him, with "a pious confidence, seek for benevolent "purposes, and he will be always directed to "the right road; and after a due continuance "in it, attain to some new and valuable truth; "whereas every other principle and motive of "examination, being foreign to the great plan

"on

"on which the universe is constructed, must lead "into endless mazes, errors, and perplexities*."

WITH respect to the indirect use of piety, it must be observed, that the tranquility, and chearfulness of mind, which results from devotion forms an excellent temper for conducting philosophical inquiries; tending to make them both more pleasant, and more successful. The sentiments of religion and piety tend to cure the mind of envy, jealousy, conceit, and every other mean passion, which both disgrace the lovers of science, and retard the progress of it, by laying an undue bias upon the mind, and diverting it from the calm pursuit of truth.

LASTLY, let it be remembered, that a taste for science, pleasing, and even honourable as it is, is not one of the highest passions of our nature, that the pleasures it furnishes are even but one degree above those of sense, and therefore that temperance is requisite in all scientifical pursuits. Besides the duties of every man's proper station in life, which ought ever to be held sacred and inviolate, the calls of piety, common friendship, and many other avocations ought generally to be heard before that of study. It is, therefore, only a small share of their leisure, that most men can be justified in giving to the pursuit of science; though this share is more or less, in proportion to a man's situation in life, his natural abilities, and the opportunity he has for conducting his inquiries.

I SHALL conclude with another passage from Dr. Hartley to this purpose. "Though the pur-

* Hartley's Observations on Man, Vol. ii. p. 245.

"suit of truth be an entertainment and em- "ployment suitable to our rational natures, and "a duty to him who is the fountain of all "knowledge and truth, yet we must make fre- "quent intervals and interruptions; else the "study of science, without a view to God and "our duty, and from a vain desire of applause, "will get possession of our hearts, engross "them wholly, and by taking deeper root "than the pursuit of vain amusements, be- "come, in the end, a much more dangerous, "and obstinate evil than that. Nothing can "easily exceed the vain-glory, self-conceit, "arrogance, emulation, and envy, that are "found in the eminent professors of the sciences, "Mathematics, Natural Philosophy, and even "Divinity itself. Temperance in these studies "is, therefore, evidently required, both in or- "der to check the rise of such ill passions, and "to give room for the cultivation of other es- "sential parts of our natures. It is with these "pleasures as with the sensible ones; our ap- "petites must not be made the measure of "our indulgence, but we ought to refer all "to a higher rule.

"BUT when the pursuit of truth is directed "by this higher rule, and entered upon with a "view to the glory of God, and the good of "mankind, there is no employment more "worthy of our natures, or more conducive to "their purification and perfection *."

* Hartley's Observations on Man, Vol. ii. p. 255, &c.

WARRINGTON,
March 1767.

PRE-

PREFACE

TO THE

SECOND EDITION.

THE method I took to distinguish the books I had seen from those I had not seen, in the catalogue of electric authors, subjoined to the first edition of this work, has been attended with the advantage I promised myself from it; several persons, who were in possession of the books I had not seen, having communicated them to me; and I have carefully perused them, and digested their contents into this second edition. Far the greater part of these new authors, the reader will perceive by the catalogue, were German, and wrote in high Dutch, a language with which, I believe, the literati of this country are but little acquainted, which might be the reason why neither myself nor my friends had ever heard of them before. Though the new materials they have supplied cannot be said to be of the first importance, many of the articles are very curious, and I hope the reader, as well as myself, will think that they have well repaid me for my trouble in learning the language.

It is certainly much to be regretted that philosophers have not one common language; but neither the theory of language in general, nor the nature and analogies of things to be expressed

preſſed by it are yet ſufficiently underſtood, to enable us to contrive a new and philoſophical one, which might be eaſily learnt, and would be completely adequate to all the purpoſes of ſcience; and Latin is a language which perſons of a philoſophical turn of mind have ſeldom leiſure to make themſelves ſo much maſters of, as to write in it with that elegance which the taſte of the age requires. Beſides, books written in Latin are but little read, at leaſt, in England; and therefore could have no ſale with us. Theſe circumſtances make it the more neceſſary, that there ſhould be, in every country, perſons poſſeſſed of a competent knowledge of foreign languages, who ſhould be attentive to the progreſs of ſcience abroad, and communicate to their countrymen all uſeful diſcoveries as they are made.

Besides the improvements in the hiſtory, and other parts of this work, the reader will find, in this edition, an addition of three intire ſections of original experiments. All that are of the leaſt conſequence are printed, and ſold ſeparately, for the benefit of thoſe who purchaſed the firſt edition.

Leeds, Jan. 1769.

ADVER-

PREFACE

TO THE

THIRD EDITION.

TO the ſecond edition of this work I made conſiderable additions, by an account of ſuch diſcoveries as had been made in the interval between that and the firſt edition; and theſe *additions* I publiſhed ſeparately for the uſe of thoſe who had purchaſed the firſt edition. But in this edition I have inſerted no account of any thing that was done after the publication of the ſecond, becauſe I reſerve an account of them for a *Continuation of the Hiſtory*, which, if God ſpare my life, I propoſe to write ſome years hence, when I hope there will be a greater ſtock of materials for it.

I HAVE, however, conſiderably improved this edition, by a fuller account of diſcoveries made by ſeveral foreigners, in conſequence of becoming poſſeſſed of the original publications, whereas before I was obliged to content myſelf with quoting them at ſecond hand. The reader will therefore find a much larger account of what was done by the Academicians del Cimento, by Mr. Du Fay, and ſome others. The alterations of the references, or the additions to them, will generally ſhow where I have done this *.

* In the account of the experiments of Mr. Monnier, thinking proper to change the place of one of the articles, I neglected

To the account I have given of the reception of Dr. Franklin's ſyſtem in France, I would add what I have ſince been informed of, viz. that Mr. Le Roi, ſecretary to the Royal Academy of Sciences, who has diſtinguiſhed himſelf by his attention to various branches of philoſophy, was the firſt who adopted this theory in that country, and became an open and ſtrenuous advocate for it. He alſo demonſtrated the principles of it by original experiments; an account of which is contained in two valuable Memoirs publiſhed among thoſe of the Royal Academy. In the former of theſe he proves, that there is an invariable diſtinction between the appearance of electric light at the points of metalic bodies as *connected with*, or *preſented to* the prime conductor, or inſulated rubber; ſo that what is called the *pencil*, is uniformly the appearance when the pointed wire is electrified poſitively, and the *ſtar* when it is negative. See Ac. Par. 1753. In another memoir for the year 1755, he ſhews, by uſing a globe of ſulphur, that the reſinous electricity of Mr. Du Fay is the very ſame thing with the negative power of Dr. Franklin. Though the ſame things had been demonſtrated by others, and eſpecially Father Beccaria, theſe philoſophers made the diſcovery independent of each other, and therefore have equal merit.

ed to cancel the former account, which the reader will pleaſe to overlook, or expunge, from p. 145. The fuller account, from the original, is at p. 155. I mention this chiefly, that if any foreigner ſhould tranſlate from this edition, he may be admoniſhed to omit the former paragraph.

Without entering into particulars, I ſhall take the liberty to acquaint the reader, that, in the ſixtieth volume of the Philoſophical Tranſactions, there are two papers of mine on electrical ſubjects, one on what I have called the *lateral exploſion*, and the other on the *conducting power of charcoal.*

In the former I ſhew that, in certain circumſtances, an electric ſpark detaches itſelf from the circuit of an exploſion to bodies placed near it, and returns to it again at the ſame inſtant. Through the air I have made this ſpark three-fourths of an inch in length, and in vacuo more than twelve inches.

In the other paper I ſhow, among other properties of charcoal, that its conducting power depends entirely on the degree of *heat* with which it is made. Some pieces do not conduct electricity at all, others as perfectly as ſilver or gold, and pieces of the former quality are always convertible into thoſe of the latter, by the application of more heat.

Also, in my *obſervations on different kinds of air*, the reader will find, that I have demonſtrated that the electric matter is, or contains phlogiſton; by ſhewing that it affects all kinds of air as phlogiſton does; particularly diminiſhing common air one fourth, and making it noxious, ſo as to make no efferveſcence with nitrous air.

It may not be amiſs to inform the reader, that the firſt tranſlation of this work was into French, by a perſon who ſeems to have done it with no other view than to have an oppor-

opportunity of expreſſing his diſlike of Dr. Franklin's ſyſtem, and of myſelf as the abettor of it, and of defending that of Mr. Nollet. In the *notes*, which all other tranſlators cenſure as in the higheſt degree illiberal, he repreſents me as being, beyond all bounds, partial to my own countrymen, and particularly unjuſt to the French; a charge from which I thought myſelf intirely exempt. I confeſs, however, that, inadvertently, I did give ſome handle to this cenſure in one paſſage, which I have therefore corrected in this edition. I have the pleaſure to be informed that a new tranſlation of this work, from this laſt edition, is undertaken by the excellent tranſlator of Dr. Franklin's Philoſophical writings, lately publiſhed. This gentleman will, I doubt not, do ample juſtice both to myſelf and to the ſubject.

CALNE, March 1775.

To the BINDER,

Place Plate I. *at the end of* Vol. I.

—— Plate II. *&c. at the end of* Vol. II.

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THE HISTORY AND PRESENT STATE OF ELECTRICITY.

PART I.

THE HISTORY OF ELECTRICITY.

PERIOD I.

EXPERIMENTS AND DISCOVERIES IN ELECTRICITY PRIOR TO THOSE OF MR. HAUKSBEE.

THE hiſtory of philoſophy contains nothing earlier than the obſervation, that yellow amber, when rubbed, has the power of attracting light bodies. Thales of Miletus, the father of the Ionic philoſophy, who flouriſhed about ſix hundred years before Chriſt, was ſo much ſtruck with this property of amber, that he imagined it was animated. But the firſt writer, who expreſsly mentions this ſubſtance, is Theophraſtus, who flouriſhed about the year 300 before Chriſt. He ſays, in his book concerning precious ſtones, ſect. 53, that amber (which he ſuppoſes to be a native foſſil) has the ſame property of attracting light bodies with the lyncurium; which, he obſerves, attracts not only ſtraws, and ſmall pieces of ſticks, but even thin pieces

of

of copper and iron. What he ſays farther of the lyncurium will be related under the article of the *tourmalin*, which Dr. Watſon has, in a manner, proved to be the ſame ſubſtance.

FROM ηλεκτρον, the Greek name for amber, is derived the term ELECTRICITY, which is now extended to ſignify not only the power of attracting light bodies inherent in amber, but other powers connected with it, in whatever bodies they are ſuppoſed to reſide, or to whatever bodies they may be communicated.

THE attractive nature of amber is occaſionally mentioned by Pliny, and other later naturaliſts; particularly by Gaſſendus, Kenelm Digby, and Sir Thomas Brown; but excepting the electricity of the ſubſtance called *jet* *, the diſcovery of which was very late (though I have not been able to find its author) no advances were made in electricity till the ſubject was undertaken by William Gilbert, a native of Colcheſter, and a phyſician at London; who, in his excellent Latin treatiſe *de magnete*, publiſhed in the year 1600, relates a great variety of electrical experiments. Conſidering the time in which this author wrote, and how little was known of the ſubject before him, his diſcoveries may be juſtly deemed conſiderable, though they appear trifling when compared with thoſe which have been made ſince his time.

To him we owe a great augmentation of the

* Mr. Boſe is ſaid to have ſhown, that the *agate* was very early known to have electric powers. Dantzick Memoirs, Vol. I. p. 179.

the lift of electric bodies, as alfo of the bodies on which electrics can act; and he has carefully noted feveral capital circumftances relating to the manner of their action, though his theory of electricity was very imperfect, as might be expected.

AMBER and jet were, as I obferved before, the only fubftances which, before the time of Gilbert, were known to have the property of attracting light bodies when rubbed; but he found the fame property in the *diamond*, *fapphire*, *carbuncle*, *iris*, *amethyft*, *opal*, *vincentina*, *Briftol ftone*, *beryl*, and *cryftal*. He alfo obferves that *glafs*, efpecially that which is clear and tranfparent, has the fame property; likewife all *factitious gems*, made of glafs or cryftal; *glafs of antimony*, moft *fparry fubftances*, and *belemnites*. Laftly, he concludes his catalogue of electric fubftances with *fulphur*, *maftic*, *fealing wax* made of gum lac tinged with various colours, *hard rofin*, *fal gem*, *talc*, and *roche alum*. Rofin, he faid, poffeffed this property but in a fmall degree, and the three laft mentioned fubftances, only when the air was clear and free from moifture.

ALL thefe fubftances, he obferves, attracted not only ftraws, but all metals, all kinds of wood, ftones, earth, water, oil; in fhort, whatever is folid, and the object of our fenfes. But he imagined that air, flame, bodies ignited, and all matter which was extremely rare was not fubject to this attraction. Grofs fmoke, he found, was attracted very fenfibly, but that which was attenuated very little.

FRICTION, he ſays, is, in general, neceſſary to excite the virtue of theſe ſubſtances; though he had one large and ſmooth piece of amber which would act without friction. But with reſpect to this he probably deceived himſelf. The moſt effectual friction, he obſerved to be that which was light and quick; and he found that electrical appearances were ſtrongeſt when the air was dry, and the wind north or eaſt, at which time electric ſubſtances would act ten minutes after excitation. But he ſays, that a moiſt air, or a ſoutherly wind almoſt annihilates the electric virtue. The ſame effect he alſo obſerved from the interpoſition of moiſture of any kind, as from the breath, and many other ſubſtances, but not always from the interpoſition of ſarſnet. He ſays that light and pure oil, ſprinkled upon electrics, after excitation, did not obſtruct their virtue; but that brandy, or ſpirit of wine, did. He alſo ſays, that cryſtal, talc, glaſs, and all other electrics loſt their virtue after being burnt or roaſted. But this was, in ſome meaſure, a miſtake. The heat of the ſun, collected by a burning glaſs, he ſays, is ſo far from exciting amber, and other electrics, that it impairs the virtue of them all; though, when electrics have been excited, they will retain their virtue longer in the ſun-ſhine than in the ſhade.

MOST of the experiments of this author were made with long thin pieces of metal, and other ſubſtances, ſuſpended freely on their centers, to the extremities of which he preſented the electrics he had excited. His experiments

periments on water were made by presenting a round drop of it upon a dry substance to the excited electric; and it is remarkable, that he observed the same conical figure of the electrified drops which Mr. Grey afterwards discovered, and which will be related more at large in its proper place. Gilbert concluded, that air was not affected by electrical attraction, because the flame of a candle was not: for the flame, he says, would be disturbed if the air had the least motion given to it.

GILBERT imagined that electrical attraction was performed in the same manner as the attraction of cohesion. Two drops of water, he observed, rush together when they are brought into contact; and electrics, he says, are virtually brought into contact with the bodies they act upon, by means of their effluvia, excited by friction.

AMONG other differences between electric and magnetic attraction, some of which are very just, and others whimsical enough, he says, that magnetic bodies rush together mutually; whereas in electrical attraction it is only the electric that exerts any power. He observes also particularly, that in magnetism there is both attraction and repulsion, but in electricity only the former, and never the latter*.

SUCH were the discoveries of our countryman Gilbert, who may justly be called the father of modern electricity, though it be

* Gilbert de magnete, Lib. 2. Cap. 2.

true that he left his child in its very infancy.

LORD BACON, in his Physiological Remains, gives a catalogue of bodies attractive and not attractive; but it differs in nothing worth mentioning from that of Gilbert, and he does not seem to have made any observations of his own relating to the subject.

ABOUT 30 years after Gilbert, NICOLAUS CABÆUS, a Jesuit at Ferrara, repeated his experiments; and found that *white wax*, almost all the *gums*, and *crude gypsum* were to be ranked among electric bodies *.

THESE remarkable phenomena relating to amber, and other electric substances, did not escape the attention of the inquisitive and sagacious Mr. Boyle, who flourished about the year 1670. He made some addition to the catalogue of electric substances, and attended to some circumstances relating to electrical attraction, which had escaped the observation of philosophers who lived before him.

HE found that the hard cake which remains after evaporating good turpentine was electrical, as also the hard mass which remains after distilling petroleum and spirit of nitre, glass of lead, the caput mortuum of amber, and the cornelian; but he could not find that property in the emerald, and he thought that glass possessed it but in a very low degree.

HE found, that the electricity of all bodies capable of having it excited in them was in-

* Dantzick Memoirs, Vol. 1, p. 180.

creased

creaſed by wiping, and warming them, previous to their being rubbed. By this means he made an electric body, no bigger than a pea, move a ſteel needle, which was freely poiſed, three minutes after he had left off rubbing it. He alſo found, that it was uſeful to have the ſurfaces of electric bodies made very ſmooth, except in the caſe of one diamond, on which he tried ſome experiments; which, though it was rough, was, he ſays, poſſeſſed of a ſtronger electric virtue than any poliſhed one he had ever met with.

He obſerved that excited electrics would attract all kinds of bodies promiſcuouſly, whether electric or not; that excited amber, for inſtance, would attract both powder of amber, and ſmall pieces of it; differing, as he takes notice, from the property of the load-ſtone, which acts only on one kind of matter. He found, that his electrics would attract ſmoke very eaſily, and takes ſome pains to account for their not ſenſibly attracting flame, which Gilbert excepted from the bodies attracted by electricity.

These attractions, he found, did not depend upon the air: for he obſerved that they took place in vacuo. He ſuſpended a piece of excited amber over a light body in a glaſs receiver, and ſaw, that when a vacuum was made, and the amber let down near the light body, it was attracted, as if it had been in the open air *. But S. Beccaria aſſerts, that

* Hiſtoire de l'ectricité.

there is no electrical attraction in a perfect vacuum.

MR. BOYLE made an experiment to try whether an excited electric was acted upon by other bodies, as strongly as it acted upon them, and it succeeded: for, suspending his excited electric, he saw that it was sensibly moved by the approach of any other body. We should now be surprised that any person should not have concluded *a priori*, that if an electric body attracted other bodies, it must, in return, be attracted by them, action and reaction being universally equal to one another. But it must be considered, that this axiom was not so well understood in Mr. Boyle's time, nor till it was afterwards explained in its full latitude by Sir Isaac Newton*.

MR. BOYLE got a glimpse, as we may say, of the electric light: for he found that a curious diamond, which Mr. Clayton brought from Italy, gave light in the dark, when it was rubbed against any kind of stuff; and he found that, by the same treatment, it became electrical. He also observed the same property in several other diamonds †.

THESE experiments of Mr. Boyle's, we see, relate only to a few circumstances attending the simple property of electrical attraction. The nearest approach that he made to the discovery of electrical repulsion was his observing, that light bodies, as feathers, &c. would

* Boyle's Mechanical production of electricity.
† Secondat's history of electricity, p. 141.

cling

cling to his fingers, and other ſubſtances, after they had been attracted by his electrics. He had ſeen but little of the electric light, and little imagined what aſtoniſhing effects would be afterwards produced by the ſame wonderful power, and how large a field he was opening for philoſophical ſpeculation in future times.

MR. BOYLE's theory of electrical attraction was, that the electric emitted a glutinous effluvium, which laid hold of ſmall bodies in its way, and, in its return to the body which emitted it, carried them back with it. One James Hartman, whoſe account of amber is publiſhed in the Philoſophical Tranſactions *, pretends to prove by experiment, that electrical attraction was really owing to the emiſſion of glutinous particles. He took two electric ſubſtances, viz. pieces of colophonia, and from one of them made a diſtillation of a black balſam, and thereby deprived it of its attractive power. He ſays, that the electric, which was not diſtilled, retained its fatty ſubſtance, whereas the other was, by diſtillation, reduced to a mere *caput mortuum*, and retained no degree of its bituminous fat. In conſequence of this hypotheſis, he gives it as his opinion, that amber attracts light bodies more powerfully than other ſubſtances, becauſe it emits oily and tenacious effluvia more copiouſly than they do.

CONTEMPORARY with Mr. Boyle was Otto

* Abridgement, Vol. 2. p. 473.

Guericke,

Guericke, Burgomaſter of Magdebourg, and the celebrated inventor of the air-pump, who is likewiſe intitled to a diſtinguiſhed place among the firſt improvers of electricity.

THIS philoſopher made his experiments with a globe of ſulphur, made by melting that ſubſtance in a hollow globe of glaſs, and afterwards breaking the glaſs from off it. He little imagined that the glaſs globe itſelf, with or without the ſulphur, would have anſwered his purpoſe as well. This globe of ſulphur he mounted upon an axis, and whirled it in a wooden frame, rubbing it at the ſame time with his hand; and by this means he performed all the electrical experiments which were known before his time.

HIS was the diſcovery, that a body once attracted by an excited electric was repelled by it, and not attracted again till it had been touched by ſome other body. In this manner he kept a feather a long time ſuſpended in the air above his ſulphur globe; but he obſerved, that if he drove it near a linen thread, or the flame of a candle, it inſtantly retreated to the globe, without having been in contact with any ſenſible body.

NEITHER the ſound, nor the light produced by the excitation of his globe, eſcaped the notice of this accurate philoſopher, though he ſeems not to have obſerved them in a very great degree: for he was obliged to hold his ear near the globe to perceive the hiſſing ſound of the electric fire; and he compares the light which it gave in the ſame circumſtances

to

to that which is ſeen when ſugar is pounded in the dark.

But the moſt remarkable experiments of this philoſopher were two, which depend upon a property of the electric fluid that has not been illuſtrated till within theſe late years; viz. that bodies immerged in electric atmoſpheres are themſelves electrified, and with an electricity oppoſite to that of the atmoſphere. Threads ſuſpended within a ſmall diſtance of his excited globe, he obſerved to be often repelled by his finger brought near them, and that a feather repelled by the globe always turned the ſame face towards it, like the moon with reſpect to the earth. This laſt experiment ſeems to have been wholly overlooked by later electricians, though it is a very curious one, and may be made with ſo much eaſe *.

To the members of the Academy *Del Cimento*, whoſe labours contributed very conſiderably to the advancement of various branches of natural knowledge, we are indebted for ſeveral obſervations on the ſubject of electricity.

They rank the electric bodies which they examined in the following order, according to the ſtrength of their attractive power, *yellow amber*, *ſealing wax*, the *roſe diamond*, and of the ſame ſtrength with this the *white ſapphire*, *emerald*, *white topaz*, *ſpinelle*, and *ruby balleis*. After theſe they ranked all *tranſ-*

* Experimenta Magdeburgica, Lib. 4. Cap. 15.

parent

parent gems, and next to the precious ſtones they placed *glaſs*, *cryſtal*, with *white and black amber*, the power of all which they ſay is very weak.

YELLOW amber appearing to them to have the greateſt power of all electric ſubſtances, they made all their experiments with it. Among other things, they found that it attracted *ſmoke*, but not *flame*; and upon this occaſion they obſerved the curious phenomenon of a *viſible electric atmoſphere*, which was afterwards re-diſcovered, and exhibited to more advantage by Dr. Franklin. For they ſay, that that part of the ſmoke which is attracted by the amber remains, and unites itſelf to it, like a ſmall cloud, and as the amber cools, it riſes in ſmoke again, and vaniſhes. At the ſame time they alſo obſerved a pretty curious effect of electrical repulſion; for they ſay that part of the ſmoke was thrown off from the amber, as from a looking-glaſs.

FLAME, they obſerved, was ſo far from being attracted by the amber, that, upon being preſented to it, it preſently deprived it of all its attractive power; for if, after it had taken up any thing, it was held to the flame, it would immediately let it go again.

THEY found that all *fluid ſubſtances* were ſenſible to the attractive power of amber, and among the reſt even *mercury*; and that when the excited amber was preſented to a large ſuperficies of any liquor, it roſe towards it in a ſmall pointed eminence; an effect which, they ſay, is beſt obſerved in *oil* or *balſam*. This obſerva-

observation, we shall find, was afterwards made again, and more particularly attended to by Mr. Grey *.

THESE gentlemen took a great deal of pains to try whether amber would attract in *vacuo*, but to no purpose, not being able to exclude the air, so as to rub the amber in vacuo, and apply it to the light body they had provided, with any effect; but neither could they make the amber act in the same confined situation even when the air was not at all excluded †.

THEY also found, with Mr. Boyle, that a piece of excited amber, suspended by a thread, was attracted by other bodies presented to it, just like a magnetical needle ‡.

LASTLY, these gentlemen found that when the excited amber was dipped in some liquors, it immediately lost its power, but not after being dipped in others. In this last class they enumerate several kinds of *oil*, *tallow*, *fat*, and *butter*, and it is now found that the conducting power of these substances is so small, that they are more properly classed among the non-conductors §.

I SHALL in the next place observe, that Mr. Boyle, Otto Guericke, and these gentlemen, made their experiments about the same time, and seemed to have derived no advantage whatever from each other's labours.

* Essays on Natural Experiments, translated by Walker, p. 128, &c.
† Ib. p. 45.
‡ Ib. p. 129.
§ Essays on Natural Experiments, translated by Walker, p. 131.

A

A MUCH finer appearance of electric light than that which Otto Guericke's sulphur globe exhibited was observed by Dr. Wall. The account of it is published in the Philosophical Transactions *.

MAKING experiments upon artificial phosphorus, which he took to be an animal oil coagulated with a mineral acid, he was led to conjecture that amber, which he supposed to be a mineral oil coagulated with a mineral volatile acid, might be a natural phosphorus; and with this view he began to make experiments upon it, the result of which, being very curious and surprising, it will be most agreeable to my readers to see in the very words of the observer himself.

"I FOUND," says he, "by gently rubbing a well polished piece of amber with my hand, in the dark, that it produced a light: whereupon I got a pretty large piece of amber, which I caused to be made long and taper, and drawing it gently through my hand, being very dry, it afforded a considerable light.

"I THEN used many kinds of soft animal substances, and found that none did so well as wool. And now new phenomena offered themselves: for, upon drawing the piece of amber swiftly through the woollen cloth, and squeezing it pretty hard with my hand, a prodigious number of little cracklings were heard, and every one of these

* Phil. Trans. abridged, Vol. 4. p. 275.

"produced

"produced a little flash of light; but when "the amber was drawn gently and slightly "through the cloth, it produced only a light "but no crackling; but by holding one's "fingers at a little distance from the amber, "a large crackling is produced, with a great "flash of light succeeding it. And, what to "me is very surprising, upon its eruption, it "strikes the finger very sensibly, wheresoever "applied, with a push or a puff, like wind. "The crackling is full as loud as charcoal on "fire, and five or six cracklings, or more, "according to the quickness of placing the "finger, have been produced from one single "friction, light always succeeding each of "them.

"Now I make no question, but upon "using a longer and larger piece of amber, "both the cracklings and light would be "much greater, because I never yet found "any crackling from the head of my cane, "though it is a pretty large one. This light "and crackling seems, in some degree, to re- "present thunder and lightning."

AFTER reciting this experiment, he gives it as his opinion, that all, or most bodies, which have electricity, give light, and that it is the light which is the cause of their being electrical. He found that light could also be produced by rubbing jet, red sealing wax, made with gum lac and cinnabar, and the diamond. He even imagined he could distinguish true from false diamonds by this test.

NOTWITHSTANDING Dr. Wall made this beautiful

beautiful diſcovery, as he imagined (for he ſeems not to have ſeen what Otto Guericke had written) of light proceeding from amber and other electric bodies, we ſee that he laboured under a great deal of confuſion and miſapprehenſion with reſpect to it. He ſays, that one thing appeared ſtrange to him in the courſe of theſe experiments, which was, that though, upon friction with wool in the day time, the cracklings ſeemed to be full as many and as large, yet that, by all the trials which he made, very little light appeared, though in the darkeſt room. He ſays that the beſt time for making theſe experiments is when the ſun is 18° below the horizon, and that when the ſun was ſo low, though the moon ſhone ever ſo bright, the light was the ſame as in the darkeſt room, which made him chuſe to call it a noctiluca.

It is remarkable that Dr. Wall compares the light and the crackling of his amber to thunder and lightning: ſo early was a ſimilarity between the effects of electricity and lightning obſerved. But little was it imagined that the reſemblance between them extended any farther than to appearances and effects. That the cauſe was the ſame in both, was a diſcovery reſerved for Dr. Franklin, in a much later period.

The great Sir Iſaac Newton, though he by no means makes a principal figure in the hiſtory of electricity, yet made ſome electrical obſervations which engaged the attention of his philoſophical friends; and which,

independent

independent of their being made by him, do well deserve to be transmitted to posterity. They seem to shew, that he was the first who observed, that excited glass attracted light bodies on the side opposite to that on which it was rubbed.

HAVING laid upon the table a round piece of glass, about two inches broad, in a brass ring, so that the glass might be one eighth of an inch from the table, and there rubbing the glass briskly, little fragments of paper laid on the table, under the glass, began to be attracted, and move nimbly to and fro. After he had done rubbing the glass, the papers would continue a considerable time in various motions; sometimes leaping up to the glass, and resting there a while, then leaping down and resting there, and then leaping up and down again; and this sometimes in lines seemingly perpendicular to the table, sometimes in oblique ones; sometimes also leaping up in one arch, and leaping down in another, divers times together, without sensibly resting between; sometimes skipping in a bow from one part of the glass to another, without touching the table, and sometimes hanging by a corner, and turning often very nimbly, as if they had been carried about in the midst of a whirlwind, and being otherwise variously moved, every paper with a different motion. Upon his sliding his finger on the upper side of the glass, though neither the glass, nor the inclosed air below, were moved, yet he observed, that the papers, as they hung under

the glaſs, would receive ſome new motion, inclining this way or that, according as he moved his finger.

SOME of the motions, as that of hanging by a corner and twirling about, and that of leaping from one part of the glaſs to another without touching the table happened but ſeldom; but, he ſays, it made him take the more notice of them *.

AN account of this experiment Sir Iſaac ſent to the members of the R. Society in the year 1675, deſiring it might be tried by them; and after ſome ineffectual attempts, and receiving further inſtructions how to make it, they at length ſucceeded, and the thanks of the ſociety were formally returned to him †.

UPON repeating the experiment with ſome variety of circumſtances, Sir Iſaac obſerves, that rubbing variouſly, or with various things, altered the caſe. At one time he rubbed a glaſs four inches broad, and one fourth thick, with a napkin, twice as much as he uſed to do with his gown, and nothing would ſtir, and yet preſently after, rubbing with ſomething elſe, the motion ſoon began. After the glaſs had been much rubbed, he thought the motions were not ſo laſting, and the day following he found the motions fainter, and more difficult to be excited than at firſt ‡.

SIR ISAAC alſo mentions electricity in two queries annexed to his treatiſe on Optics, from

* Birch's Hiſt. of the R. Society, Vol. 3. p. 260, &c.
† Ib. 271. ‡ Ib. p. 270.

which

which we learn, that he imagined electric bodies when excited emitted an elastic fluid, which freely penetrated glass, and that the emission was performed by the vibratory motions of the parts of the excited bodies *.

PERIOD II.

THE EXPERIMENTS AND DISCOVERIES OF MR. HAUKSBEE.

AFTER Gilbert, Mr. Boyle, and Otto Guericke, Mr. Haukſbee, who wrote in the year 1709, diſtinguiſhed himſelf by experiments and diſcoveries in electricity. He firſt obſerved the great electric power of glaſs, the light proceeding from it, and the noiſe occaſioned by it, together with a variety of phenomena relating to electrical attraction and repulſion. He was indefatigable in making experiments, and there are few perſons to whom we are more indebted for a real advancement of this branch of knowledge. This will appear from the following ſuccinct account of his experiments, related not exactly in the order in which he has publiſhed them, but according to their connection. This method I have choſen, as beſt adapted to give the moſt diſtinct view of the whole.

I SHALL firſt relate the experiments he made concerning *electrical attraction and re-*

* Newton's Optics, octavo, p. 314, and 317.

pulsion, in many of which we shall see reason to admire his ingenious contrivances, and shall see that little was added to his observations, till the capital discovery of a *plus* and *minus* electricity by Dr. Watson and Dr. Franklin, and the farther illustration of that doctrine by Mr. Canton.

THE most curious of his experiments concerning electrical attraction and repulsion are those which shew the direction in which those powers are exerted.

HAVING tied threads round a wire hoop, and brought it near to an excited globe or cylinder, he observed, that the threads kept a constant direction towards the center of the globe, or towards some point in the axis of the cylinder, in every position of the hoop; that this effect would continue for about four minutes after the whirling of the globe ceased, and that the effect was the same whether the wire was held above or under the glass; or whether the glass was placed with its axis parallel, or perpendicular to the horizon.

HE observed, that the threads pointing towards the center of the globe were attracted and repelled by a finger presented to them; that if the finger, or any other body, was brought very near the threads, they would be attracted; but that if it were brought to the distance of about an inch, they would be repelled, the reason of which difference he did not seem to understand *.

* Physico-Mechanical Experiments, p. 75.

HE

He tied threads to the axis of a globe and cylinder, and found that they diverged every way in ſtraight lines from the place where they were tied, when the globe was whirled and rubbed. In both caſes, he ſays, the threads would be repelled by the finger held on the oppoſite ſide of the glaſs, even without touching the glaſs; though they would ſometimes ſuddenly jump towards it *. He obſerved farther, that by blowing with his mouth towards the glaſs, at three or four feet diſtance, the threads would have a very conſiderable motion given to them.

He found that threads, hanging freely in an unexcited globe, at reſt, would be moved by the approach of any excited electric at a conſiderable diſtance, except in moiſt weather; which failure he accounts for, by ſuppoſing the moiſture on the ſurface of the glaſs prevented the free paſſage of the electric effluvia through it †.

The varieties he obſerved on the appearances and properties of the *electric light*, are even more curious and ſurpriſing than his diſcoveries concerning electric attraction and repulſion; and it is ſomething remarkable that Mr. Haukſbee's tranſition to electric light was like that of Dr. Wall, viz. from the light of phoſphorus.

Mr. Hauksbee firſt produced a conſiderable quantity of light by ſhaking quick-

* Phyſico-Mechanical Experiments, p. 78.
† Ib. p. 160.

silver in a glass vessel, out of which the air was exhausted. Sometimes what he calls strange flashes of pale light were seen darting in a variety of directions, when the mercury was put in motion within an exhausted receiver *. But the discovery was probably accidental, and he did not seem, at that time, to know the reason of the appearance. He called this light the *mercurial phosphorus*, and did not consider the glass as any way concerned in producing it.

He also found, that this appearance of electric light (which he still calls the mercurial phosphorus) did not require a very perfect vacuum, nor even a near approach to it †. Nay he sometimes produced that appearance of light by shaking mercury in a vessel, in which the air was of the same density with the external atmosphere; but still he had no idea of the glass contributing to the phenomenon ‡.

He observed a strong light in vacuo, and a small one in the open air, from rubbing amber upon woollen, but seems to have considered it as any hard body rubbing against a soft one ||. He also observed a vivid purple, and afterwards a pale light produced by rubbing glass upon woollen in vacuo §. He says that every fresh glass first gave a purple, and then a pale light, and that woollen tinctured

* Physico-Mechanical Experiments, p. 12.
† Ib. p. 14.
‡ Ib. p. 18.
|| Ib. p. 26.
§ Ib. p. 32.

with

with ſalt or ſpirits produced a new, ſtrong, and fulgurating light *.

In the following experiments we find his ideas of electric light much more diſtinct, and the appearances the ſame that are uſually exhibited by our preſent electrical machines, the ſtructure of which, we ſhall find to be nearly the ſame with thoſe which he uſed.

He provided himſelf with a machine in which he could whirl a glaſs globe; and he obſerved, when the air was extracted out of it, that, upon applying his hand to the globe, a ſtrong light appeared on the inſide, and, upon letting in the air, he obſerved the light on the outſide alſo; but with ſome very conſiderable differences in its appearances, ſtriking upon his fingers, and other bodies held near the globe. He alſo obſerved, upon this occaſion, that one fourth of an atmoſphere in the globe did very little diminiſh the light within. It is pleaſing to obſerve, that the ſimilar appearance in this experiment, and that with mercury in vacuo before-mentioned, made him ſuſpect, though only ſuſpect, that the light produced in the former caſe proceeded not from the mercury, but from the glaſs.

The next experiment is of a very delicate and curious nature. It is not to be wondered at, that Mr. Haukſbee did not underſtand the circumſtances which contributed to it, as

* Phyſico-Mechanical Experiments, p. 34.

the explication of it depends upon principles which were not discovered till a much later period by Mr. Canton.

HOLDING an exhausted globe within the effluvia of an excited one, he observed a light in the exhausted globe, which presently died away, if it was kept at rest; but which was revived, and continued very strong, if the exhausted globe was kept in motion. Presenting an exhausted tube to the effluvia of an excited globe, it produced what he calls an interrupted flashing light. He imagined that the exhausted globe was excited by the attraction of the effluvia from the other globe, so little did he understand the true cause of this curious experiment*. When he says that light is producible by the effluvia of one glass falling upon another, he adds; that electric (by which he means attractive) matter, is not to be brought forth by any such feeble strokes. He had before observed that, upon rubbing an exhausted tube, it discovered no attractive power, nor gave any light outwards, but only inwards.

HE found that when the friction was performed in vacuo, no electricity (that is attraction) could be produced †; but that though the *attractive quality* required the presence both of the external and internal air, in order to its shewing itself, yet the *light* requires the presence of only one of them in order to its appearance; for that either a glass globe full

* Physico-Mechanical Experiments, p. 82.
† Ib, 242.

of

of air rubbed *in vacuo*, or with its air exhausted and rubbed *in pleno*, would produce a very considerable light *.

He says also, that those lights are less sensibly affected by the return of air, which are produced by the attrition of exhausted glass in pleno, than those which are produced by the attrition of glass full of air in vacuo; for that, in the former case, no great alteration was found in the light or colour, until a certain quantity of air was let into the inside of the exhausted glass; but that, in the latter case, both light and colour were sensibly changed, upon every admission of air to the outside of the full glass †.

The greatest electric light Mr. Hauksbee produced, was when he enclosed one exhausted cylinder within another not exhausted, and excited the outermost of them, putting them both in motion. Whether their motions conspired or not, he observed, made no difference. When the outer cylinder only was in motion, he says, the light was very considerable, and spread itself over the surface of the inner glass. What surprised him most was, that after both glasses had been in motion some time, during which his hand had been applied to the surface of the outer glass, the motion of both ceasing, and no light at all appearing; if he did but bring his hand again near the surface of the outer glass,

* Physico-Mechanical Experiments, p. 248.
† Ib. p. 248.

there

there would be flashes of light, like lightning, produced in the inner glass; as if, he says, the effluvia from the outer glass had been pushed with more force upon it by means of the approaching hand *. This experiment was similar to those which he made with the excited and exhausted globe, and with the exhausted tube; and his reasoning upon it shews, that he was still far from being fully apprized of all the circumstances attending this fact.

THE next experiments which I shall relate of Mr. Hauksbee's, are those which shew the great copiousness, and extreme subtilty of electric light. They are really amazing, and have not yet been pursued in the manner they deserve.

HE lined more than half of the inside of a glass globe with sealing wax, and having exhausted the globe, he put it in motion; when, applying his hand to excite it, he saw the shape and figure of all the parts of his hand distinctly and perfectly, on the concave superficies of the wax within. It was as if there had only been pure glass, and no wax interposed between his eye and his hand. The lining of wax, where it was spread the thinnest, would but just allow the sight of a candle through it in the dark; but in some places the wax was, at least, one eighth of an inch thick; yet even in those places, the light and the figure of his hand were as distinguishable through it, as any where else. Nay

† Physico-Mechanical Experiments, p. 87.

though,

though, in ſome places, the ſealing wax did not adhere ſo cloſely to the glaſs as in others, yet the light on theſe appeared juſt as on the reſt *.

THESE experiments ſucceeded equally with pitch inſtead of ſealing wax. And he obſerved, that when the air was let into the glaſs, every part of it, the lined part and the unlined, ſeemed to attract with equal vigour †. Melted flowers of ſulphur had no ſuch effect, but common ſulphur anſwered as well as ſealing wax, or pitch. In both theſe laſt experiments the ſulphur was found to have been ſeparated from the glaſs ‡.

USING a large quantity of common ſulphur in the ſame manner, the light in the inſide was four times as great, but the figure of his fingers was not ſo diſtinguiſhable as in the former caſes. He likewiſe obſerved, that on the part near the axis, where the ſubſtance of the ſulphur was the greateſt, no light was produced; which he attributed, chiefly, to the ſlowneſs of the motion in that place §.

UPON the admiſſion of a ſmall quantity of air into the globe, thus partially lined with ſealing wax, the light wholly diſappeared on the part covered with the wax, but not on the other.

HE alſo obſerved, that when all the air was let in, and the hoop of threads before-

* Phyſico-Mechanical Experiments, p. 168.
† Ib. 269. ‡ Ib. 274. § Ib. 275.

mentioned

mentioned held over the glaſs, the threads were attracted at greater diſtances by the part which was coated with the wax than by the other: when all the air was exhauſted, he ſays, the wax would attract bodies placed near the out-ſide of the glaſs; that even in this caſe, the threads preſerved their central direction, though not ſo vigorouſly as when the air was let in; but that they would not be attracted at all, when there was no wax on the inſide of the exhauſted globe.

MR. HAUKSBEE was not unattentive to the *ſound* made by the emiſſion of the electric effluvia, or to the manner in which it affected the ſenſe of *feeling*. He obſerved, that when an excited tube of glaſs attracted various bodies, and threw light upon them, as they were held near it, a noiſe, which he calls a *ſnapping*, was likewiſe heard. He alſo ſays, that the rubbed tube, held near the face, gave a feeling, as if fine hairs had been drawn over it; and when he repeated the experiment of whirling and rubbing the glaſs globe, he obſerved the light to proceed from it with ſome noiſe, and to make a kind of preſſure upon the finger, when it was held within half an inch of it *.

NOR was Mr. Haukeſbee's attention confined to the electric power of *glaſs*. He made experiments with a globe of *ſealing wax*, in the center of which was a globe of wood; from which he concluded, that the electricity

* Phyſico-Mechanical Experiments, p. 65.

of

of ſealing wax was, in general the ſame with that of glaſs, but different from it in degree. He could not make any light adhere to his finger when preſented to the excited ſealing wax, any more than when it was preſented to an exhauſted and excited globe of glaſs.

HE provided himſelf, in like manner, with a globe of ſulphur, and another of roſin with a mixture of brick duſt, but the ſulphur could hardly be excited at all; whereas the roſin acted more powerfully than the ſealing wax had done. This he aſcribed to its being uſed while it was warm: for, in the ſame warm ſtate, it attracted leaf braſs without any attrition at all *.

HE ſays, that the excited roſin gave no light in the dark, and the ſulphur but little †.

WITH reſpect to the power of electricity in general, he obſerved, that a ſlight friction was ſufficient to excite it, and that a greater preſſure, or a more violent motion did not conſiderably increaſe it ‡. He ſays, that all the phenomena of electricity were improved by warmth; and diminiſhed by moiſture; which he attributed to the reſiſtance that the aqueous particles gave to the effluvia; and, like Mr. Boyle, and others before him, he was confirmed in this hypotheſis, by finding, that the interpoſition of linen cloth prevented any effects from being obſerved beyond it.

* Phyſico-Mechanical Experiments, p. 154.
† Ib. p. 156. ‡ Ib. p. 54.

HE

HE alſo obſerved, that when the tube was filled with other matter than air, as with dry writing ſand (which he actually tried) the attractive power of the effluvia was conſiderably abated; but he did not know what kind of bodies would produce that effect. He himſelf obſerves, that he found the electric virtue of a ſolid cylinder of glaſs to be, not indeed quite ſo ſtrong as that of a hollow tube, but more permanent *.

THAT Mr. Haukſbee, after all, had no clear idea of the diſtinction of bodies into electrics and non-electrics, appears from ſome of his laſt experiments, in which he attempted to produce electric appearances from metals, and from the reaſons he gives for his want of ſucceſs in thoſe attempts. "From "theſe experiments," he ſays, "I may ſafe-"ly conclude, that if there be any ſuch "quality as light to be excited from a braſs "body, under the forementioned circum-"ſtances," viz. of whirling and rubbing, "all the attrition of the ſeveral bodies I have "uſed for that purpoſe, have been too weak "to force it from it. And indeed, con-"ſidering the cloſeneſs of the parts of metals, "and with what firmneſs they adhere, en-"tangle, and attract one another, a ſmall "degree of attrition is not ſufficient to put "their parts into ſuch a motion as to pro-"duce an electrical quality, which quality, "under the forementioned circumſtances, I

* Phyſico-Mechanical Experiments, p. 64.

"take to be the appearance of light in ſuch a
"medium."

CONSIDERING what great ſucceſs Mr. Haukſbee had with his globe of glaſs, and his machine to give motion to it, it is ſurpriſing that the uſe of it ſhould have been ſo long diſcontinued after his death. To this circumſtance we may perhaps, in a great meaſure, aſcribe the ſlow progreſs that was afterwards made in electrical diſcoveries. Mr. Haukſbee's ſucceſſors confined themſelves to the uſe of tubes. I ſuppoſe becauſe they were lighter, more portable, and more eaſily managed in the experiments which they chiefly attended to: but the uſe of the globe would certainly have put them much ſooner in the way of making the capital diſcoveries, which were afterwards made in electricity.

PERIOD III.

THE EXPERIMENTS AND DISCOVERIES OF MR. STEPHEN GREY, WHICH WERE MADE PRIOR TO THOSE OF MONSIEUR DU FAY, AND WHICH BRING THE HISTORY OF ELECTRICITY TO THE YEAR 1733.

NOTWITHSTANDING the important diſcoveries of Mr. Haukſbee, and the promiſing appearance they made, as an opening to farther diſcoveries, we find, after him, a great chaſm in the hiſtory of electricity, an interruption of diſcoveries, and, as far as we can learn, of experiments too, for the ſpace of near twenty years; and at a time when philoſophical knowledge of every other kind was making the moſt rapid progreſs, under the auſpices of the great Sir Iſaac Newton. But the attention of this great man happened to be engaged by other ſubjects, and this very circumſtance might be the reaſon why the attention of other philoſophers were alſo diverted from electricity.

AFTER this long interval, commences a new æra in the hiſtory of electricity; in which we ſhall have the works of another labourer in this new field of philoſophy to contemplate, viz. Mr. Stephen Grey, a penſioner at the Charter Houſe. No perſon who ever applied to this ſtudy was more aſſiduous in making experiments, or had his heart more intirely

in

in the work. This will appear by the prodigious number of experiments he made, and some considerable discoveries with which his perseverance was crowned; as well as by the self-deceptions, to which his passionate fondness for new discoveries exposed him.

BEFORE the year 1728, Mr. Stephen Grey had often observed, in electrical experiments made with a glass tube, and a down feather tied to the end of a small stick, that, after its fibres had been drawn towards the tube, they would, upon the tube's being withdrawn, cling to the stick, as if it had been an electric body, or as if there had been some electricity communicated to the stick, or to the feather. This put him upon thinking, whether, if the feather were drawn through his fingers, it might not produce the same effect, by acquiring some degree of electricity. This experiment succeeded accordingly, upon his first trial; the small downy fibres of the feather being attracted by his finger, when held near it; and sometimes the upper part of the feather with its stem would be attracted also.

IT will be obvious to every electrician, that the success of this experiment depended upon other principles, than those to which he had a view in making it. Proceeding, however, in the same manner, he found the following substances to be all electric; *hair*, *silk*, *linen*, *woollen*, *paper*. *leather*, *wood*, *parchment*; and *ox gut* in which leaf gold had been beaten. He made all these substances very warm, and some of them quite hot before he rubbed them.

He found light emitted in the dark by the ſilk and the linen, but more eſpecially by a piece of white *preſſing paper*, which is of the ſame nature with card paper. Not only did this ſubſtance, when made as hot as his fingers could bear, yield a light; but, when his fingers were held near it, a light iſſued from them alſo, attended with a crackling noiſe, like that produced by a glaſs tube, though not at ſo great a diſtance from the fingers *.

THE preceding experiments bring us to the eve of a very conſiderable diſcovery in electricity, viz. the communication of that power from native electrics, to bodies, in which it is not capable of being excited; and alſo to a more accurate diſtinction of electrics from non-electrics. I ſhall relate the manner in which theſe important diſcoveries were made pretty fully, but, at the ſame time, as ſuccinctly as poſſible.

IN the month of February, 1729, Mr. Grey, after ſome fruitleſs attempts to make metals attractive, by heating, rubbing, and hammering, recollected a ſuſpicion which he had ſome years entertained; that, as a tube communicated its light to various bodies when it was rubbed in the dark, it might poſſibly, at the ſame time, communicate an electricity to them, by which had hitherto been underſtood only the power of attracting light bodies. For this purpoſe he provided himſelf with a tube three feet five inches long, and

* Philoſophical Tranſactions abridged, Vol. viii. p. 9.

near

near one inch and two tenths in diameter; and to each end was fitted a cork, to keep the dust out when the tube was not in use.

The first experiments he made upon this occasion were intended to try, if he could find any difference in its attraction when the tube was stopped at both ends by the corks, and when left entirely open; but he could perceive no sensible difference. It was, however, in the course of this experiment that, holding a down feather over against the upper end of the tube, he found that it would fly to the cork, being attracted and repelled by it, as well as by the tube itself. He then held the feather over against the flat end of the cork, and observed, that it was attracted and repelled many times together; at which, he says, he was much surprised, and concluded, that there was certainly an attractive virtue communicated to the cork by the excited tube.

He then fixed an ivory ball upon a stick of fir, about four inches long; when, thrusting the other end into the cork, he found, that the ball attracted and repelled the feather, even with more vigour than the cork had done, repeating its attractions and repulsions many times successively. He afterwards fixed the ball upon long sticks, and upon pieces of brass and iron wire, with the same success; but he observed, that the feather was never so strongly attracted by the wire, though it were held very near the tube, as by the ball at the end of it.

When a wire of any confiderable length was ufed, its vibrations, caufed by the action of rubbing the tube, made it troublefome to manage. This put Mr Grey upon thinking, whether, if the ball were hung to a packthread, and fufpended by a loop on the tube, the electricity would not be carried down the line to the ball; and he found it to fucceed according to his expectation. In this manner he fufpended various bodies to his tube, and found all of them to be capable of receiving electricity in the fame manner.

After trying thefe experiments with the longeft light canes and reeds that he could conveniently ufe, he afcended a balcony twenty-fix feet high; and, faftening a ftring to his tube, he found, that the ball at the end of it would attract light bodies in the court below.

He then afcended to greater heights, and by putting his long canes in the end of his tube, and faftening a long ftring to the end of the canes, he contrived to convey the electricity to much greater diftances than he had done before; till, being able to carry it no farther perpendicularly, he next attempted to carry it horizontally; and from thefe attempts arofe a difcovery, of which he was not in the leaft aware when he began them.

In his firft trial he made a loop at each end of a packthread, by means of which he fufpended it, at one end, on a nail driven into a beam, the other end hanging downwards. Through the loop which hung down, he put the

the line to which his ivory ball was faſtened, fixing the other end of it by a loop on his tube; ſo that one part of the line, along which the electricity was to be conveyed, viz. that to which the ball was faſtened, hung perpendicular, the reſt of the line lay horizontal. After this preparation, he put the leaf braſs under the ivory ball, and rubbed the tube, but not the leaſt ſign of attraction was perceived. Upon this he concluded, that when the electric virtue came to the loop of the packthread, which was ſuſpended on the beam, it went up the ſame to the beam; ſo that none, or very little, of it went down to the ball; and he could not, at that time, think of any method to prevent it.

On June the 30th, 1729, Mr. Grey paid a viſit to Mr. Wheeler, to give him a ſpecimen of his experiments; when, after having made them from the greateſt heights which the houſe would admit, Mr. Wheeler was deſirous of trying whether they could not carry the electric virtue to a greater diſtance horizontally. Mr. Grey then told him of the fruitleſs attempt he had made to convey it in that direction: upon which Mr. Wheeler propoſed to ſuſpend the line to be electrified by another of *ſilk*, inſtead of *packthread*; and Mr. Grey told him, it might do better, on account of its ſmallneſs; as leſs of the virtue would probably paſs off by it than had done by the thick hempen line, which he had uſed before. With this expedient, they ſucceeded far beyond their expectations.

THE firſt experiment they made after this expedient occurred to them, was in a matted gallery at Mr. Wheeler's houſe, July 2d, 1729, about ten o'clock in the morning, as Mr. Grey, after his uſual manner, has minutely recorded it. About four feet from the end of the gallery, they faſtened a line acroſs the place. The middle part of this line was ſilk, the reſt pack thread. They then laid the line to which the ivory ball was hung, by which the electric virtue was to be conveyed to it from the tube, and which was eighty feet and a half in length, acroſs this ſilken line, ſo that the ball hung about nine feet below it. The other end of the line was, by a loop, faſtened to the tube, which they excited at the other end of the room. After this preparation, they put the leaf braſs under the ivory ball, and, upon rubbing the tube, it was attracted, and kept ſuſpended for ſome time.

THE gallery not permitting them to go any greater lengths with a ſingle line of communication, they contrived to return the line, making the whole length of it almoſt twice that of the gallery, or about one hundred and forty-ſeven feet, which anſwered very well. But, ſuſpecting that the attraction would be ſtronger without doubling or returning the line, they made uſe of a line one hundred and twenty-four feet long, running in one direction in the barn; and, as they expected, they found the attraction ſtronger than

when the line had been returned in the gallery.

JULY the 3d, proceeding to make more returns of the line, the ſilk which ſupported it happened to break, not being able to bear the weight of it, when ſhaken with the motion that was given to it by rubbing the tube. Upon this they endeavoured to ſupport it by a ſmall iron wire, inſtead of the ſilken ſtring; but this alſo breaking, they made uſe of a braſs wire a little thicker. But this braſs wire, though it ſupported the line of communication very well, did not anſwer the purpoſe of theſe young electricians: for, upon rubbing the tube, no electricity was perceived at the end of the line. It had all gone off by the braſs wire which ſupported it. They had recourſe to braſs wires, as being ſtronger than their ſilken lines, and no thicker; for the ſame reaſon that they had before uſed ſilken lines in preference to hempen ſtrings; becauſe they could have them ſtronger, and at the ſame time ſmaller. But the reſult of this experiment convinced them, that the ſucceſs of it depended upon their ſupporting lines being *ſilk*, and not, as they had imagined, upon their being *ſmall*. For the electric virtue went off as effectually by the ſmall braſs wire, as it had done by the thick hempen cord.

BEING obliged, therefore, to return to their ſilken lines, they contrived them to ſupport very great lengths of the hempen line of communication; and actually conveyed the electric virtue ſeven hundred and ſixty-five feet,

nor did they perceive that the effect was sensibly diminished by the distance *.

In the same manner in which *silk* was found to be a non-conductor, it is probable that, about the same time, *hair*, *rosin*, *glass*, and perhaps some other electric substances, were found to have the same property, though the discovery be no where particularly mentioned: for we shall presently find Mr. Grey making use of them, to insulate the bodies which he electrified.

After this, Mr. Grey and his friend amused themselves with trying how *large* surfaces might be impregnated with the electric effluvia; electrifying a large map, table cloth, &c. They also carried the electric virtue several ways at the same time, and to a considerable distance each way.

The magnetic effluvia, they found, did not in the least interfere with the electric; for when they had electrified the load stone, with a key hanging to it, they both attracted leaf brass like other substances.

Some time after this, Mr. Wheeler, in the absence of Mr. Grey, electrified a red-hot poker, and found the attraction to be the same as when it was cold. He also suspended a live chicken upon the tube by the legs, and found the breast of it strongly electrical †,

* Phil. Trans. abridged, Vol. vii. p. 15.
† Ib. p. 16.

In August, 1729, Mr. Grey advanced one step farther in his electrical operations. He found that he could convey the electric virtue from the tube to the line of communication without touching it, and that holding the excited tube near it was sufficient. Repeating his former experiments with this variation, in conjunction with Mr. Wheeler, and among others, carrying the electric virtue several ways at the same time without touching the line, they always observed, that the attraction was strongest at the place which was most remote from the tube; a fact which they might have observed, if they had attended to it, in their former experiments *.

Some time in the same month, Mr Wheeler and Mr. Grey in conjunction made some experiments, in order to try whether the electric attraction was in proportion to the quantity of matter in bodies; and with this view they electrified a solid cube of oak, and another of the same dimensions which was hollow; but they could not perceive any difference in their attractive power; though it was Mr. Grey's opinion, that the electric effluvia passed through all the parts of the solid cube †.

On the 13th of August in the same year, Mr. Grey made another improvement in his electrical apparatus, by finding that he could electrify a *rod*, as well as a *thread*, without

* Phil. Transf. abridged, Vol. vii. p. 17.
† Ib. p. 17.

inserting

inſerting any part of it into his excited tube. He took a large pole twenty-ſeven feet long, two inches and one half in diameter at one end, and one inch and one half at the other. It was a ſort of wood which is called horſe-beach, and had its rind on. This pole he ſuſpended horizontally by hair lines, and at the ſmall end of the pole he hung a cork, by means of a packthread about one foot long, and put a ſmall leaden ball upon the cork, to keep the packthread extended. Then the leaf braſs being put under the cork, the tube rubbed, and held near the larger end of the pole, the cork ball at the oppoſite end attracted the leaf braſs ſtrongly, to the height of an inch or more. Mr. Grey alſo obſerved, that though the leaf braſs was attracted by any part of the pole, it was not near ſo ſtrongly as by the cork *.

ABOUT the beginning of September, Mr. Grey made experiments, to ſhew that the electric effluvia might be carried in a circle, as well as along lines, and be communicated from one circle to another; and alſo that it might be done whether the circles were vertical, or horizontal.

ABOUT the latter end of autumn, or the beginning of winter 1729, Mr. Grey reſumed his inquiries after other electrical bodies, and found many more to have the ſame property, but he mentions only the dry leaves of ſeveral trees; from whence he concluded, that

* Phil. Tranſ. abridged, Vol. vii. p. 18.

the leaves of all vegetables had that attractive virtue *.

WE are now advanced to a new scene of Mr. Grey's electrical experiments, viz. upon *fluids*, and upon *animal bodies*. Having no other method of trying whether any substances could have the electric virtue communicated to them, but by making them raise light bodies placed upon a stand under them, it may easily be imagined, that he could not well contrive to put a fluid body into that situation. The only thing that Mr. Grey could do in this way, was to make use of a bubble, in which form a fluid is capable of being held in a state of suspension. Accordingly on March 23d and 25th, 1730, he dissolved soap in Thames water, and suspending a tobacco pipe, he blew a bubble at the head of it; and, bringing the excited tube near the small end, he found the bubble to attract leaf brass to the height of two, and of four inches †.

APRIL the 8th, 1730, Mr. Grey suspended a boy on hair lines in a horizontal position, just as all electricians had, before, been used to suspend their hempen lines of communication, and their wooden rods; then, bringing the excited tube near his feet, he found that the leaf brass was attracted by his head with much vigour, so as to rise to the height of eight, and sometimes of ten inches. When the leaf brass was put under his feet, and the

* Phil. Transf. abridged, Vol. vii. p. 19.
† Ibid.

tube

tube brought near his head, the attraction was small; and when the leaf brass was brought under his head, and the tube held over it, there was no attraction at all. Mr. Grey does not attempt to assign any reason for these appearances. It was not till many years after this time, that the influence of *points* in receiving and emitting the electric effluvia was observed. While the boy was suspended, Mr. Grey amused himself with making the electricity operate in several parts of his body, at the same time; and at the end of long rods, which he made him hold in his hands, and in diversifying the experiment several other ways *.

It is curious to observe the inference which Mr. Grey makes from these experiments. By them, says he, we see, that animals receive a greater quantity of electric fluid than other bodies; and that it may be conveyed from them several ways at the same time, to considerable distances. He had no idea that the bodies of animals receive electricity only by means of the moisture that is in them, and that this hempen line of communication, and his wooden rods could not have been electrified at all, if they had been perfectly dry.

In all these experiments Mr. Grey observed, that the leaf brass was attracted to a much greater height from the top of a narrow stand than from the table; and, at least, three times

* Phil. Trans. abridged, Vol. vii. p. 20.

higher

higher than when it was laid on the floor of the room.

ABOUT this time Mr. Grey communicated to the Royal Society his ſuſpicion, that bodies attracted more or leſs according to their *colour*, though the ſubſtance was the ſame, and the weight and ſize equal. He ſays, he found red, orange, and yellow attracted at leaſt three or four times ſtronger than green, blue, or purple; but he forbore communicating a more particular account of them, till he had tried a more accurate method which, he ſays he had thought of, to make the experiments. The communication, however, was never made. The thing itſelf was only a deception, as will be ſhewn in ſome ſubſequent experiments made by Monſieur du Fay *.

MR. GREY, having found that he could communicate electricity to a bubble of ſoap and water, was encouraged to attempt communicating it to water itſelf. In order to this, he electrified a wooden diſh full of water, placed on a cake of roſin, or a pane of glaſs, and obſerved, that if a ſmall piece of thread, a narrow ſlip of thin paper, or a piece of ſheet glaſs was held over the water, in an horizontal poſition, at the diſtance of an inch or ſomething more, they would be attracted to the ſurface of the water and then repelled; but he imagined that theſe attractions and repulſions were not repeated ſo often as they would have been, if the body had been ſolid.

* Phil. Tranſ. abridged, Vol. vii. p. 22.

BUT

BUT he afterwards contrived to ſhew the effect of electricity upon water in another and more effectual manner. As this experiment was very curious and exhibited an appearance which was quite new to the electricians of thoſe times, I ſhall relate the particulars of it very fully, and generally in Mr. Grey's own words *.

HE filled a ſmall cup with water higher than the brim, and when he had held an excited tube over it, at the diſtance of about an inch or more, he ſays, that if it were a large tube, there would firſt ariſe a little mountain of water from the top of it, of a conical form; from the vertex of which there proceeded a light, very viſible when the experiment was performed in a dark room, and a ſnapping noiſe, almoſt like that which was made when the finger was held near the tube, but not quite ſo loud, and of a more flat ſound. Upon this, ſays he, immediately the mountain, if I may ſo call it, falls into the reſt of the water, and puts it into a tremulous and waving motion.

WHEN he repeated this experiment in the ſun ſhine, he perceived that very ſmall particles of water were thrown from the top of the mountain; and that, ſometimes, there would ariſe a fine ſtream of water from the vertex of the cone, in the manner of a fountain, from which there iſſued a fine ſteam or vapour, whoſe particles were ſo ſmall as not

* Phil. Tranſ. abridged, Vol. vii. p. 23.

to

to be ſeen; yet, he ſays, he was certain it muſt be ſo; ſince the under ſide of the tube was wet, as he found when he came to rub it afterwards. He adds, that he had ſince found, that though there does not always ariſe that cylinder of water, yet that there is always a ſtream of inviſible particles thrown on the tube, and ſometimes to that degree as to be viſible on it.

When ſome of the larger cups were uſed (his ſizes were from three fourths to one tenth of an inch in diameter) which, he ſays were to be filled as high as could be done without running over; the middle part of the ſurface, which was flat, would be depreſſed, upon the approach of the tube, into a concave, and the parts towards the edge be raiſed; and that when the tube was held over againſt the ſide of the water, little conical protuberances of water iſſued out from it horizontally; and, after the crackling noiſe, returned to the reſt of the water; and that ſometimes ſmall particles would be thrown off from it, as from the ſmall portions of it above mentioned.

THIS laſt experiment he repeated with hot water, and found that it was attracted much more ſtrongly, and at a much greater diſtance than before. The ſteam ariſing from the vertex was in this caſe viſible, and the tube was ſprinkled with large drops of water.

HE tried theſe experiments, in the ſame manner, with quickſilver, which was likewiſe raiſed up, but, by reaſon of its gravity, not to ſo great a height as the water: but, he ſays, that

that the ſnapping noiſe was louder, and laſted much longer than it did with the water *.

IT is not eaſy to know what to make of the next ſet of experiments which engaged the attention of Mr. Grey, or how far he deceived himſelf in the reſults of them. He fancied that he had diſcovered a *perpetual attractive power* in all electric bodies which did not require heating, rubbing, or any kind of attrition to be excited. The following experiments, he imagined proved the diſcovery.

HE took nineteen different ſubſtances, which were either roſin, gum lac, ſhell lac, bees wax, ſulphur, pitch, or two or three of theſe differently compounded. Theſe he melted in a ſpherical iron ladle, except the ſulphur, which was beſt done in a glaſs veſſel. When theſe were taken out of the ladle, and their ſpherical ſurfaces hardened, he ſays, they would not attract till the heat was abated, or till they came to a certain degree of warmth; that then there was a ſmall attraction, which increaſed till the ſubſtance was cold, when it was very conſiderable †.

THE manner in which he preſerved theſe ſubſtances in a ſtate of attraction, was by wrapping them in any thing which would keep them from the external air. At firſt, for the ſmaller bodies, he uſed white paper, and for the larger ones, white flannel; but he afterwards found that black worſted ſtockings

* Phil. Tranſ. abridged, Vol. vii p. 24.
† Ibid.

would

would do as well. Being thus cloathed, he put them into a large firm box; where they remained, till he had occasion to make use of them.

He observed these bodies for thirty days, and found that they continued to act as vigorously as on the first or second day; and that they retained their power till the time of his writing, when some of them had been prepared above four months.

He makes the most particular mention of a large cone of stone sulphur, covered with a drinking glass in which it was made; and says, that whenever the glass was taken off, it would attract as strongly as the sulphur, which was kept covered in the box. In fair weather, the glass would attract also, but not so strongly as the sulphur, which never failed to attract, let the wind or the weather be ever so variable; as would all the other bodies, only in wet weather, the attraction was not so great as in fair weather.

He also mentions a cake of melted sulphur, which he kept without any cover, in the same place with the body abovementioned, and where the sun did not shine upon them; and says, that it continued to attract till the time of his writing; but that its attraction was not one tenth part of that of the cone of sulphur which was covered.

These attractions he tried by a fine thread hanging from the end of a stick. He held the electric body in one hand, and the stick in the other; and could perceive the attrac-

 tion

tion at as great a diſtance as he could hold them.

At the time of his writing, he was upon the ſubject of permanent electricity in glaſs, but had not then completed his experiments *.

Great light will be thrown upon theſe experiments of Mr. Grey by ſome that will be hereafter related of Mr. Wilcke. It is probable that the glaſs veſſel in theſe experiments was poſſeſſed of one electricity, and the ſulphur, &c. of the other. But the two electricities were not diſcovered till afterwards.

We are now come to a different ſet of electrical experiments, made by Mr. Grey and Mr. Wheeler in conjunction, ſimilar to ſome of Mr. Haukſbee's.

In the firſt place, Mr. Grey made ſome experiments, which, probably unknown to him, had been made before by Mr. Boyle, on excited glaſs, and ſeveral other bodies *in vacuo*, and found that they would attract at very near the ſame diſtance as *in pleno*. To determine this, he ſuſpended the excited ſubſtance in a receiver of an air-pump, and when it was exhauſted, he let the electric down to a proper diſtance from ſome light bodies, placed on a ſtand below. The event was, as near as could be judged, the ſame in vacuo as in the open air, if the experiment was made in the ſame receiver, and if the electric was brought to the light bodies at the ſame diſtance of time from the act of excitation †.

* Phil. Tranſ. abridged, Vol. vi. p. 27. † Ibid.

About the latter end of Auguſt 1732, Mr. Grey and Mr. Wheeler ſuſpended, from the top of a receiver, a white thread, which hung down to the middle of it. Then exhauſting the receiver, and rubbing it, the thread was attracted vigorouſly. When it was at reſt, and hung perpendicularly, the excited tube attracted it; and when the tube was taken away ſlowly, the thread returned to its perpendicular ſituation; but the tube being removed haſtily, the thread jumped to the oppoſite ſide of the receiver. This laſt effect followed, if the hand was haſtily removed from the receiver; and at firſt it appeared, in both caſes, unaccountable to them; but upon farther conſideration, they concluded, that it proceeded from the motion of the air, made by the tube, or the hand, which ſhook off the attraction on that ſide, and not on the other *. They alſo found, that an excited tube would attract the thread through another receiver, which was put over that in which it was ſuſpended. And, ſometime after, Mr. Wheeler found that the thread was attracted through five receivers put one over another, and all exhauſted: he even thought that, in this caſe, the attraction was rather ſtronger than when a ſingle receiver was uſed. N. B. The more effectually to keep any thing of moiſture out of the receivers, which would have been of bad conſequence in this experiment, inſtead of wet leather, he made uſe of a cement made

* Phil. Tranſ. abridged, Vol. vii. p. 56. † Ibid. p. 97.

of wax and turpentine, which Mr. Boyle used in his experiments *.

These two gentlemen, about the same time, made a curious experiment which, they say, shewed that attraction is communicated thro' opaque, as well as transparent bodies, not in vacuo. But a little knowledge of metal, as a conductor of electricity, would have saved them the trouble they gave themselves. They took a large hand-bell, and taking out the clapper, they suspended a cork, besmeared with honey, from the top of it; and set it on a piece of glass, on which they had put some leaf brass. The excited tube was then brought near several parts of the bell; and, upon taking it up, several pieces of leaf brass were found sticking to the cork, and others were removed from the places in which they had been left, having, probably, been attracted by the bell †.

We see by how small steps advances were made in the science of electricity, by some experiments made by Mr. Grey, 16th June 1731, and which he has thought worth recording; though they contain hardly any thing which we should think new, notwithstanding the discoveries appeared pretty considerable to him.

He electrified a boy standing on cakes of rosin, as strongly as he had before electrified him when suspended on hair lines. He afterwards electrified a boy suspended on hair lines,

* Phil. Trans. abridged, Vol. vii. p. 97. † Ibid. 96.

by

by means of a line of communication from another boy who was electrified, at some feet distance from him. He varied this experiment with rods and boys several ways; and concluded from it, that the electric virtue might not only be carried from the tube, by a rod, or line, to distant bodies, but that the same rod, or line, would communicate that virtue to another rod, or line, at a distance from it; and that, by this other rod, or line, the attractive force might be carried to still more distant bodies. This experiment shews that Mr. Grey had not properly considered the line of communication, and the body electrified by it, as one and the same thing, in an electrical view, differing only in form, as they were both alike conductors of electricity.

In December following, Mr. Grey carried this experiment something farther, by conveying electricity to bodies which did not touch the line of communication, making it pass through the center of hoops standing on glass. One of his hoops was twenty, another forty inches in diamer *.

* Phil. Transf. abridged, Vol. vii. p. 100.

PERIOD IV.

The experiments and discoveries of Mr. Du Fay.

HITHERTO the spirit of electricity seems to have been confined to England; but, about this time, we find that it had passed the seas, and that ingenious foreigners were ambitious of distinguishing themselves, and acquiring reputation in this new field of glory. Mr. Du Fay, intendant of the French king's gardens, and member of the academy of sciences at Paris, assiduously repeated the experiments above-mentioned of Mr. Grey, and likewise added to the common stock many new ones of his own. To him we are also indebted for the observation of several general properties of electricity, or rules concerning the method of its action, which had not been taken notice of before, and which reduced to fewer propositions what had been discovered concerning it. These experiments were comprised in eight memoirs, inserted in the History of the Academy of Sciences for the years 1733, 1734 and 1737; and an account of some of them also makes an article in the Philosophical Transactions, dated December 27, 1733. The first of his memoirs contain a history of electricity, brought down to the year 1732*.

* Dantzick Memoirs, Vol. i. p. 195.

He

He found that all bodies, except metallic, soft, and fluid ones, might be made electric, by first heating them, more or less, and then rubbing them on any sort of cloth. He also excepts those substances which grow soft by heat, as gum; or which dissolve in water, as glue. He also remarked, that the hardest stone and marble required more chafing and heating than other bodies, and that the same rule obtains with regard to woods; so that box, lignum vitæ, and other kinds of very hard wood must be chafed almost to a degree of burning; whereas fir, lime-tree, and cork require but a moderate heat*. Among the more perfect electrics he enumerates all *vitrifications*, the Venetian and Muscovite *talc*, the *phosphorus of Berne*, *gypsum*, *transparent selenites*, and in general all *transparent stones*, of whatsoever kind†. Of *salts* he tried only *alum*, and *sugar candy*, both of which he found to be electrical, after warming and rubbing; and he supposed that all the rest would be found to have the same properties, if due precautions were observed in making the experiments. He also observed the electricity of all kinds of *hair*, *silk*, *wool*, and *cotton*, and especially, what appeared to him very extraordinary, the powerful electricity of the *back of a dog*, and still more that of a *cat*‡.

He found that not only damp air, but also great heat was prejudicial to electricity, and

* Phil. Transf. abridged, Vol. viii. p. 393.
† Ac. Par. 1733. M. p. 105. ‡ Ib. p. 107.

that his experiments often failed in the warmest hours of a moderately hot day *. Also when he heated several bodies, in order to excite their electric power, he found that in some the hottest, and in others the coolest parts only were electrical †.

He says, that, pursuing Mr. Grey's experiments, to make water receive electricity, he found, that all bodies, without exception, whether solid, or fluid, were capable of it, when they were placed on glass, or sealing-wax slightly warmed, or only dried, and the excited tube was brought near them. He particularly mentions his having made the experiments with ice, lighted wood, red hot iron ‡, coal, and every thing that happened to be at hand at the time; and to his great surprize, remarked, that such bodies as were of themselves the least electric, had the greatest degree of electricity communicated to them by the approach of the excited tube §.

To determine whether the transparency of glass was the cause of the transmission of the electric effluvia through that substance (for no one at that time suspected that bodies could be affected by electricity through glass in consequence of its being actually permeable to the electric matter) he used sealing wax, and found that light bodies were affected through that

* Dantzick Memoirs, Vol. i. p. 211.
† Ac. Par. 1733, M. p. 109.
‡ Nollet's Recherches, p. 212
§ Ac. Par. 1733. M. p. 115.

opaque

opaque ſubſtance, as much as through glaſs *.

He refutes Mr. Grey's aſſertion concerning the different electricity of differently coloured bodies, and ſhews that it proceeded not from the colour as a *colour*, but from the ſubſtance which was employed in dying it †.

In order to determine whether ſimple *colour* had any influence in electricity, he introduced a beam of the ſun's light into a darkened room, and made his experiments on bodies illuminated with the different primitive colours; and he found that, in no reſpect whatever, did the different colours make any difference in the power of receiving, communicating, or deſtroying electricity ‡.

Having communicated the electricity of the tube, by means of a packthread, after Mr. Grey's manner, he obſerved, that the experiment ſucceeded better for wetting the line; and though he made the experiment at the diſtance of one thouſand two hundred and fifty-ſix feet, when the wind was high, the line making eight returns, and paſſing through two different walks of a garden, that the electric virtue was ſtill communicated §. He alſo made uſe of glaſs tubes, ſometimes lined with ſealing wax, and found that it anſwered as well as ſilk lines, and was often more conveniently applied ‖.

Our ingenious electrician varied this experiment by ſuſpending two cords with their

* Ac. Par. 1737. M. p. 338. † Ibid. 1733. M. p. 337.
‡ Ib. p. 334. § Phil. Tranſ. abridged, Vol. viii. p. 3.5.
‖ Ac. Par. 1733. M. p. 345.

ends oppoſite to one another, and found that when they were placed at no greater diſtance than an inch, the electricity was communicated without any ſenſible diminution from the one to the other; but at the diſtance of a foot it was hardly ſenſible. When the cords were placed at the diſtance of three inches, he found that a lighted candle held between them did not prevent the tranſmiſſion of electricity, nor did the blaſt of a pair of bellows *. Bringing wood and other conducting ſubſtances, ſuſpended by ſilk, to this electrified cord, he found, as he had concluded *a priori*, that it loſt only part of its electricity; the whole quantity being equally diſtributed between them †.

The electric ſpark from a living body, which makes a principal part of the diverſion of gentlemen and ladies, who come to ſee experiments in electricity, was firſt obſerved by Mr. du Fay, accompanied at that time, as in moſt of his experiments, by the Abbé Nollet, who, afterwards, we ſhall find, did himſelf obtain a diſtinguiſhed name among electricians.

MR. DU FAY, having got himſelf ſuſpended on ſilk lines, as Mr. Grey had done the child mentioned above, obſerved, that, as ſoon as he was electrified, if another perſon approached him, and brought his hand within an inch, or thereabouts, of his face, legs, hands, or cloaths, there immediately iſſued

* Ac. Par. 1733. M. p. 350. † Ibid. p. 352.

from

from his body one or more pricking ſhoots, attended with a crackling noiſe. He ſays this experiment occaſioned to the perſon who brought his hand near him, as well as to himſelf, a little pain, reſembling that of the ſudden prick of a pin, or the burning from a ſpark of fire; and that it was felt as ſenſibly through his cloaths, as on his bare face, or hands. He alſo obſerves, that, in the dark, thoſe ſnappings were ſo many ſparks of fire *.

THE Abbé Nollet ſays he ſhall never forget the ſurprize, which the firſt electrical ſpark which was ever drawn from the human body excited, both in Mr. du Fay, and in himſef ‡.

HE ſays that thoſe ſnappings and ſparks were not excited, if a bit of wood, of cloth, or of any other ſubſtance than a living human body, was brought near him; except metal, which produced very nearly the ſame effect as the human body. He was not aware, that it was owing to points, or partial dryneſs, in the ſubſtances which he mentions, that they did not take a full and ſtrong ſpark. He ſeems alſo to have been under ſome deception, when he imagined that the fleſh of dead animals gave only an uniform light, without any ſnapping, or ſparks §.

FROM this circumſtance, however, he, at that time concluded, that the bodies of liv-

* Phil. Tranſ. Vol. viii. p. 395. Ac. Par. 1733. M. p. 353.

‡ Leçons de Phyſique, Vol. vi. p. 408.

§ Phil. Tranſ. abridged, Vol. viii. p. 395. Ac. Par. 1734. M. 714.

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ing animals, (and also metals) were surrounded with an atmosphere of vapour, which was actually set on fire by electric light *.

He observed, that a cat emitted an electric spark, which evidently gave her pain, when the finger was brought to any part of her body, after she had been stroked, while she was sitting on a silk cushion. This must have appeared very extraordinary, before it was known, that the electric matter passed from the hand to the cat, in the act of rubbing †.

With the electric sparks, he imagined he could have fired inflammable substances; and he made several attempts with tinder and gunpowder, but without success: he found no appearance of real fire. This was a discovery reserved for the Germans ‡.

The two next capital observations of Mr. Du Fay I shall repeat in his own words, because they are important and curious; and yet the former of them is little more than what Otto Guericke had observed before him. "I "discovered," he says, "a very simple principle, which accounts for a great part of "the irregularities, and, if I may use the "term, of the caprices, that seem to accompany most of the experiments in electricity. "This principle is, that electric bodies attract all those which are not so, and repel "them as soon as they are become electric, "by the vicinity or contact of the electric "body. Thus leaf gold is first attracted by

* Dantzick Memoirs, Vol. i. p. 215. 230.
† Ibid. p. 216. ‡ Ibid. p. 229.

"the

" the tube; acquires electricity by approach-
" ing it, and, consequently, is immediately
" repelled by it; nor is it re-attracted, while
" it retains its electric quality. But if, while
" it is thus sustained in the air, it chance to
" light on some other body, it straightway
" loses its electricity, and consequently is re-
" attracted by the tube; which, after having
" given it a new electricity, repels it a second
" time; and this repulsion continues as long
" as the tube keeps its power. Upon apply-
" ing this principle to various experiments of
" electricity, one will be surprised at the
" number of obscure and puzzling facts,
" which it clears up." By the help of this principle, he, particularly, endeavours to explain several of Mr. Hauksbee's experiments *.

" CHANCE, he says, has thrown in my
" way another principle more universal and
" remarkable than the preceding one; and
" which casts a new light upon the subject of
" electricity. The principle is, that there
" are *two kinds of electricity*, very different
" from one another; one of which I call
" *vitreous*, the other *resinous* electricity. The
" first is that of glass, rock-crystal, precious
" stones, hair of animals, wool, and many
" other bodies. The second is that of am-
" ber, copal, gum lac, silk, thread, paper,
" and a vast number of other substances.
" The characteristics of these two electricities

* Phil. Transf. abridged, Vol. viii. p. 396.

" are

"are, that they repel themselves, and attract each other. Thus a body of the vitreous electricity repels all other bodies possessed of the vitreous, and on the contrary, attracts all those of the resinous electricity. The resinous, also, repels the resinous, and attracts the vitreous. From this principle, one may easily deduce the explanation of a great number of other phenomena; and it is probable, that this truth will lead us to the discovery of many other things."

This very capital discovery was, as the ingenious author acknowledges, perfectly accidental, having been made in consequence of casually observing (which, he says, was to his great surprize) that, having caused a piece of leaf gold to be repelled, and suspended in the air, by an excited glass tube, and meaning likewise to chase it about the room by a piece of excited gum copal, instead of being repelled by it, as it was by the glass tube, it was eagerly attracted. The same was the case with sealing-wax, and the other substances enumerated above. He also observed, that when a piece of leaf gold was electrified by excited sealing-wax, &c. it was constantly attracted by excited glass, but repelled by excited sealing-wax, &c. *

Our ingenious electrician was, however, too hasty in concluding, as he did, that the two electricities which he had discovered were

* Ac. Par. 1733, M. p. 627.

altogether

altogther independent of the ſubſtance with which the electrics were rubbed. All the difference, he ſays, produced by a change of the rubber, was that of *more or leſs* of the ſame kind*. We ſhall find that, in a much later period, the contrary was diſcovered to be true by Mr. Canton.

IN order to know, immediately, to which of the two claſſes of electricity any body belonged, he made a ſilk thread electrical, and brought it to the body, when it was excited. If it repelled the thread, he concluded it was of the ſame electricity with it, viz. reſinous; if it attracted it, he concluded it was vitreous †. He had alſo other ingenions methods to aſcertain the ſame thing ‡.

HE alſo obſerved, that communicated electricity had the ſame property as the excited. For having electrified, by the glaſs tube, balls of wood or ivory; he found them to repel the bodies which the tube repelled, and to attract thoſe which the tube attracted. If they had the reſinous electricity communicated to them, they obſerved the ſame rule, by attracting thoſe bodies which had the vitreous electricity communicated to them, and repelling thoſe which had received the reſinous. But, he obſerves, the experiment would not ſucceed, if the bodies were not made equally electrical; for, if one of them was weakly electrical, it would be attracted by that which

* Ac. Par. 1733, M. p. 639.
† Phil. Tranſ. abridged, Vol. viii. p. 397.
‡ Ac. Par. 1733, M. p. 639.

was

was much more ſtrongly electrical, of whatever quality it was.

THIS diſcovery of the two electricities was certainly a capital one, but was, notwithſtanding, left very imperfect by Mr. Du Fay. We ſhall ſee that Dr. Franklin found, that, in all probability, the vitreous electricity is poſitive, or a redundancy of electric matter; and the reſinous, negative, or a want of it; and that Mr. Canton has diſcovered, that it depends upon the ſurface of the electric bodies, and of the rubber, whether the electricity be poſitive or negative.

THE doctrine of two different electricities, produced by exciting different ſubſtances, conſiderable as the diſcovery of it was, ſeems to have been dropped after Mr. Du Fay, and thoſe effects aſcribed to other cauſes; which is an inſtance that ſcience ſometimes goes backwards.

MR. DU FAY himſelf ſeems, at laſt, to have adopted the opinion, which generally prevailed to the time of Dr. Franklin; that the two electricities differed only in degree, and that the ſtronger attracted the weaker: not conſidering that, upon this principle, bodies poſſeſſed of the two electricities ought to attract one another leſs forcibly, than if one of them had not been electrified at all, which is contrary to fact.

IT will be ſeen that, many years after, Mr. Kinnerſley of Philadelphia, a friend of Dr. Franklin's, being at Boſton in New England, made ſome experiments which again

ſhewed

ſhewed the difference of the two electricities. He communicated thoſe experiments to Dr. Franklin, who repeated and explained them *.

MR. DU FAY was the firſt perſon who endeavoured to excite a tube in which air was condenſed, and, to his great ſurprize, found the attempt ineffectual. Suſpecting this might be owing to moiſture, which he might have forced into the tube, in uſing his condenſing inſtrument, he cemented a large copper eolipile to his tube, and compreſſed the air in it, by putting the eolipile upon the fire. After this, he turned a cock, which he had placed to prevent the return of the compreſſed air, and diſengaged the tube from the eolipile; but he ſtill found the excitation to be impoſſible †. The Abbé Nollet, who aſſiſted at moſt of this gentleman's experiments, declares himſelf not ſatisfied even with this precaution; thinking that the non-excitation of the tube might ſtill be owing to the moiſture, which always exiſts in the air, and the particles of which muſt be drawn nearer together by condenſation ‡. In anſwer to this objection, Mr. Boulanger ſays, that a ſmall glaſs full of water poured into a tube, and immediately thrown out again, will not deſtroy the excitability of the glaſs near ſo much as the condenſed air §.

MR. DU FAY found no difference in the excitation of a glaſs tube whether it was filled with warm *ſand* or not; but when the tube was

* See his Letters. † Ac. Par. 1734. M. p. 489.
‡ Nollet's Recherches, p. 258. § Boulanger, p. 132.

cool it was not so easily excited. The excitation was more obstructed by *bran*, and much more by *water*, warm or cold; though, he says, that the electricity was not quite destroyed by it *.

MR. DU FAY took a good deal of pains to ascertain the effect of electricity *in vacuo*, but his conclusion can hardly be depended upon. For, he says, that *glass*, and other substances possessed of the same kind of electricity, are hardly capable of being excited *in vacuo*; whereas *amber*, and the substances of that class, are excited as easily, and as vigorously *in vacuo*, as in the open air. The *vacuum* he made seems to have been as good as can be made by the better kind of our air-pumps †.

This philosopher was the first who observed that electric substances attract the dew more than conductors. He observed that a glass vessel, placed on a metal cup, and set in the open air all day, will often be wet when the metal is dry. S. Beccaria accounts for this fact, by supposing that alterations in the electricity of the air easily produce correspondent alterations in the electricity of metals, in which the electric fluid moves with the utmost ease, but not in glass. Whenever, therefore, the state of the electric fluid in the air is altered, the glass is electrified *plus* or *minus*, and therefore attracts the vapours in the air ‡.

* Ac. Par. 1733. M. p. 341.
† Ac. Par. 1734. M. p. 489.
‡ Beccaria del elettricismo naturale et artificiale, p. 179.

It

IT must be observed, that Mr. Granville Wheeler, in the autumn of the year 1732, made several curious experiments, relating to the repulsive force of electricity. These he repeated to Mr. Grey in the summer following, and designed to communicate them, through his hands, to the Royal Society; but, deferring the execution of it from time to time, he was informed that Mr. Du Fay had taken notice of the same solution of the repulsive force. Upon this he laid aside all thoughts of communicating his discovery to the public: but, finding that his experiments were different from those of Mr. Du Fay, he was persuaded to publish them in the Philosophical Transactions for the year 1739.

THE experiments were made by threads of various kinds, and other substances, hanging down from silk lines, and generally made to repel one another by the approach of an excited tube. The result of them all he comprised in the three following propositions. 1st. That bodies made electrical, by communication with an excited electric, are in a state of repulsion with respect to such excited bodies. 2dly. That two, or more bodies, made electrical by communicating with an excited electric, are in a state of repulsion with respect to one another. 3dly. Excited electrics do themselves repel one another *.

ONE of his experiments, to prove the second of these propositions, deserves to be

* Phil. Transf. abridged, Vol. viii. p. 411.

mentioned for its curiosity. He tied a number of silk threads together, by a knot at each extremity; when, upon electrifying them, the threads repelled one another, and the whole bundle was swelled out into a beautiful spherical figure; so that he could with pleasure, he says, observe the knot at the bottom rising upwards, as the electricity and mutual repulsion of the threads increased; and he could not help imagining his bundle of silks to resemble a bundle of muscular fibres.

By way of corollary to the same proposition, he observes, that it suggests, more plainly than any other know experiment, a reason for the dissolution of bodies in menstrua; viz. that the particles of the solvend, having imbibed particles of the menstrua, so as to be saturated with them, the saturated particles become repulsive of one another, separate, and fly to pieces *.

* Philosophical Transactions abridged, Vol. viii. p. 410.

PERIOD

PERIOD V.

THE CONTINUATION AND CONCLUSION OF MR. GREY'S EXPERIMENTS.

MR. GREY, upon resuming his experiments, expresses great satisfaction, that his former observations had been confirmed by so judicious a philosopher as Mr. Du Fay; who, he acknowledges, had made several new ones of his own, particularly that important *luciferous one*, as he calls it, recited above; which, put him upon making the experiments which follow, and which were made in the months of July and August 1734*.

As Mr. Du Fay had said, that the snappings and the sparks, he had mentioned, were strongly excited by a piece of metal, presented to the person suspended on silk lines; Mr. Grey concluded, that if the person and metal should change places, the effect would be the same. He, accordingly, suspended several pieces of metal on silk lines, beginning with the common utensils, which were at hand, as the poker, tongs, fire shovel, &c. and found, that, when they were electrified, they gave sparks, in the same manner as the human body had done in like circumstances.

* Phil. Transf. abridged, Vol. viii. p. 397.

This was the origin of *metallic conductors*, which are in uſe to this day *.

MR. GREY did not, at the time above-mentioned, think of making his experiments in the dark, in order to ſee the light proceeding from the iron; not imagining, that electricity, communicated to metals would have produced ſuch ſurpriſing phenomena, as, he ſays, he afterwards found it to do.

CONTINUING his experiments at Mr. Wheeler's, they found, that the fleſh of dead animals exhibited, very nearly, the ſame appearances as that of living animals, contrary to the aſſertion of Mr. Du Fay.

BUT what moſt ſurpriſed Mr. Grey, and the gentlemen then preſent, in the experiments he made upon that occaſion, was the

* Phil. Tranſ. abridged, Vol. viii. p. 398.

In order the more conveniently to communicate electricity to the iron bar, Mr. Du Fay (who adopted the contrivance from Mr. Grey) faſtened to the end of it a bundle of *linen threads*, to which he applied his excited tube. He was led to prefer the thread for this purpoſe, in conſequence of having found that, of the flexible ſubſtances, *wool*, *ſilk*, *cotton*, or *linen*; the laſt was moſt attracted by an excited electric. He ſuſpended them all to the ſame bar, and brought an excited glaſs tube to an equal diſtance from them all at the ſame time, and obſerved that they were attracted in the order in which I have mentioned them, *wool* the leaſt, and *linen* the moſt. Ac. Par. 1737. M. p. 137. Theſe linen threads of Mr. Du Fay kept their ground in a much improved ſtate of the electrical apparatus, when globes were ſubſtituted in the place of tubes, but now *ſmall wires* are univerſally uſed in preference to them.——Mr. Du Fay alſo, in order to determine what *metal* was the moſt proper for this purpoſe, procured equal cylinders of gold, ſilver, copper, braſs, lead, iron, and tin, and having placed them ſo as to conſtitute one cylinder, he drew ſparks from each of them in their turn, when the whole was electrified; but he could not, in any reſpect, perceive the leaſt difference in them. Ac. Par. 1737. M. p. 132.

pheno-

phenomenon above referred to, and what he nows calls *a cone*, or *pencil of electric light*; such as is commonly seen to issue from an electrified point. As this was the first time that this phenomenon, which is now so common, was distinctly seen, I shall relate the experiment, of which it was the result, at large.

Mr. Grey, and his friends, provided themselves with an iron rod four feet long, and half an inch in diameter, pointed at each end, but not sharp. Suspending this iron rod upon silk lines in the night; and applying the excited tube to one end of it, they perceived not only a light upon that end, but another issuing from the opposite end, at the same time. This light extended itself, in the form of a cone, whose vertex was at the end of the rod: and Mr. Grey says, that he and his company could plainly see, that it consisted of separate threads, or rays of light, diverging from the point of the rod, the exterior rays being incurvated. This light appeared at every stroke they gave the tube.

They likewise observed, that this light was always attended with a small hissing noise, which, they imagined, began at the end next the tube, increasing in loudness till it came to the opposite end. He says, however, that this noise could not be heard, but by persons who stood near the rod, and attended to it*.

* Phil. Transf. abridged, Vol. viii. p. 398.

MR. GREY, repeating thoſe experiments in the September following, after his return to London, obſerved an appearance, which he ſays, ſurpriſed him very much. After the tube had been applied to the iron rod, as before, when the light, which had been ſeen at both ends, had diſappeared; it was viſible again upon bringing his hand near the end of the rod; and, upon repeating this motion of his hand, the ſame phenomenon appeared for five or ſix times ſucceſſively; only the rays were, at each time, ſhorter than the other. He alſo obſerved, that theſe lights, which were emitted by the tube upon the approach of his hand, were, like the others, attended with a hiſſing noiſe.

HE took notice, that the light which appeared on the end next the tube, when it was held oblique to the axis of the rod, had its rays bending towards it; and that, all the time he was rubbing the tube, thoſe flaſhes of light appeared upon every motion of his hand up or down the tube, but that the largeſt flaſhes were produced by the motion of his hand downwards *.

WHEN he uſed two or three rods, laying them either in a right line, or ſo as to make any angle with each other, and applied the tube to any one of their ends; he obſerved, that the fartheſt end of the farther rod exhibited the ſame phenomena as one ſingle rod †.

* Phil. Tranſ. abridged, Vol. viii. p. 399.
† Ib. p. 400.

USING

USING a rod pointed only at one end, he obſerved, that the other end gave but one ſingle ſnap, but that it was much louder than the greateſt of thoſe which were given by the point of the rod; alſo that the pain, reſembling pricking or burning, was more ſtrongly felt, and that the light was brighter and more contracted.

CONNECTING a pewter plate with the iron rod, and filling the plate with water, he obſerved the ſame light, the ſame puſhing of the finger, as he calls it, and the ſame ſnapping, as when the experiment was made with the empty plate. And when the experiment was made with water, in the day-light, it appeared to riſe in a little hill, under the finger which was preſented to it; and, after the ſnapping noiſe, fell down again, putting the water into a waving motion near the place where it had riſen.

THESE effects were the ſame with thoſe which he had before obſerved top roceed from the immediate action of the tube, but by theſe experiments, he ſays, he found (what, no doubt, appeared a real advance in the ſcience to him) that an actual flame of fire, together with an exploſion, and ebullition of cold water, might be produced by communicative electricity. What he adds is ſo remarkable, that I ſhall repeat his own words. "And although theſe "effects are at preſent but *in minimis*, it is "probable, in time, there may be found out "a way to collect a greater quantity of the "electric fire, and conſequently to increaſe

"the

"the force of that power; which, by several "of these experiments, *si licet magnis componere parva*; seems to be of the same "nature with that of thunder and lightning *."

How exactly has this prophecy been fulfilled in the discoveries of the Leyden electricians, and Dr. Franklin; the former having discovered the amazing accumulation of the electric power, in what is called the Leyden phial; and the latter having proved the matter of lightning to be the very same with that of electricity; though Mr. Grey might possibly mention thunder and lightning only by way of common comparison.

ON February the 18th, 1735, Mr. Grey, repeating the experiments of the iron rods with wooden ones, found all the effects to be similar, but much weaker; as it is now well known must have been the case; wood being so imperfect a conductor, and only in proportion to the moisture it contains.

AT the same time, he relates, that the repeating the electrification of water, he found, that the phenomena before mentioned were produced, not only by holding the tube near the water, but when it was removed, and the finger afterwards brought near it †.

MAY the 6th of the same year, he again suspended a boy on silk, and found that this boy was able to communicate the electric fire,

* Phil. Transf. abridged, Vol. viii. p. 401.
† Ibid. p. 403.

first

firſt to one, and then to ſeveral perſons ſtanding upon electric bodies.

MR. GREY ſeems ſtill to have imagined, that electricity depended, in ſome meaſure, upon colour. The boy ſuſpended on blue lines, he ſays, retained his power of attraction fifty minutes; on ſcarlet lines, twenty-five minutes; and on orange coloured lines, twenty-one minutes. By theſe experiments, he ſays, we ſee the efficacy of electricity on bodies ſuſpended upon lines of the ſame ſubſtance, but of different colour *.

BUT the greateſt deception which this ingenious gentleman ſeems to have lain under, was occaſioned by the experiments which he made with balls of iron, to obſerve the revolution of light bodies about them. The paragraph relating to theſe experiments, being the laſt which Mr Grey wrote, I ſhall give it at length as a curioſity.

" I HAVE lately made," ſays he, " ſeveral
" new experiments upon the projectile and
" pendulous motion of ſmall bodies by elec-
" tricity; by which ſmall bodies may be
" made to move about large ones, either in
" circles, or in ellipſes; and thoſe either
" concentric, or eccentric to the center of the
" larger body, about which they move, ſo as
" to make many revolutions about them.
" And this motion will conſtantly be the
" ſame way that the planets move about the
" ſun, viz. from the right hand to the left,

* Phil. Tranſ. abridged, Vol. viii. p. 403.

" or

"or from west to east. But these little pla-
"nets, if I may so call them, move much
"faster in their *apogeon*, than in the *perigeon*
"parts of their orbits; which is directly con-
"trary to the motion of the planets about the
"sun*."

These experiments Mr. Grey had thought of but a very little while before his last illness, and had not time to complete them; but the progress he had made in them he revealed, on the day before his death, to Dr. Mortimer, then secretary to the Royal Society. He said they struck him with new surprize every time he repeated them, and hoped that, if God would spare his life a little longer, he should, from what these phenomena pointed out, bring his electrical experiments to the greatest perfection. He did not doubt but, in a short time, he should be able to astonish the world with a new sort of planetarium, never before thought of; and that, from these experiments, might be established a certain theory, to account for the motions of the grand planetarium of the universe. These experiments, fallacious as they are, deserve to be briefly recited, together with those which were made in consequence of them after Mr. Grey's death. I shall relate them in Mr. Grey's own words, as they were delivered to Dr. Mortimer, on his death-bed.

Place a small iron globe, said he, of an inch, or an inch and a half in diameter, on

* Phil. Trans. abridged, Vol. viii. p. 404.

the

the middle of a circular cake of roſin, ſeven or eight inches in diameter, gently excited; and then a light body ſuſpended by a very fine thread, five or ſix inches long, held in the hand over the center of the table, will, of itſelf, begin to move in a circle round the iron globe, and conſtantly from weſt to eaſt. If the globe be placed at any diſtance from the center of the circular cake, it will deſcribe an ellipſe, which will have the ſame eccentricity, as the diſtance of the globe from the center of the cake.

If the cake of roſin be of an elliptical form, and the iron globe be placed in the center of it, the light body will deſcribe an elliptical orbit, of the ſame eccentricity with the form of the cake.

If the iron globe be placed in, or near, one of the foci of the elliptical cake, the light body will move much ſwifter in the apogee, than in the perigee of its orbit.

If the iron globe be fixed on a pedeſtal, an inch from the table, and a glaſs hoop, or a portion of a hollow glaſs cylinder, excited, be placed round it; the light body will move as in the circumſtances mentioned above, and with the ſame varieties.

He ſaid, moreover, that the light body would make the ſame revolutions, only ſmaller, round the iron globe placed on the bare table, without any electrical body to ſupport it; but he acknowledged he had not found the experiment ſucceed, if the thread was ſupported by any thing but a human hand;

hand; though, he fancied, it would have ſucceeded, if it had been ſupported by any animal ſubſtance, living or dead *.

MR. GREY went on to recite to Dr. Mortimer other experiments ſtill more fallacious; which, out of regard to his memory, I ſhall forbear to quote. Let the chimeras of this great electrician teach his followers, in the ſame, and ſtill but newly opened field of philoſophy, a proper degree of caution in their reaſonings from induction. Let not the example, however, diſcourage any perſon from trying what may appear improbable; but let it induce a man to delay the publication of his diſcoveries, till they have been perfectly aſcertained, and performed in the preſence of others. In experiments of great delicacy, a ſtrong imagination will have great influence even upon the external ſenſes; of which we ſhall have frequent inſtances in the courſe of this hiſtory.

DR. MORTIMER himſelf ſeems to have been deceived by theſe experiments of Mr. Grey. He ſays, that, in trying them after his death, he found, that the light body would make revolutions round bodies of various ſhapes and ſubſtances, as well as round the iron globe; and that he had actually tried the experiment, with a globe of black marble, a ſilver ſtandiſh, a ſmall chip box, and a large cork †.

* Phil. Tranſ. abridged, Vol. viii. p. 404, 405.
† Ibid. p. 405.

THESE experiments of Mr. Grey were tried by Mr. Wheeler, and other gentlemen, at the Royal Society's houſe, and with a great variety of circumſtances; but no concluſion could be drawn from what they at that time obſerved. Mr. Wheeler himſelf took a great deal of pains to verify them, with various ſucceſs; and at laſt he gave it as his opinion, that a deſire to produce the motion from weſt to eaſt was the ſecret cauſe, that determined the pendulous body to move in that direction, by means of ſome impreſſion from Mr. Grey's hand, as well as his own; though he was, at the ſame time, perſuaded, that he was not ſenſible of giving any motion to his hand himſelf*.

MR. DU FAY, in the Memoirs of the Academy of Sciences for the year 1737, acknowledges that theſe experiments of Mr. Grey and Dr. Mortimer did not ſucceed with him. But ſays, they were the only ones of Mr. Grey that had not; and, with a temper becoming a philoſopher, adds, that he doth not, therefore, ſay, that they never had ſucceeded; but ſeems rather willing to attribute the failure with himſelf, to his omitting ſome circumſtance, not mentioned by thoſe gentlemen, though, unknown to them, it might be of principal conſequence to the experiment †. He was afterwards informed of the reſult of the laſt experiment in England on this ſubject, agreeing with his own ‡.

* Phil. Tranſ. abridged, Vol. viii. p. 418.
† Dantzick Memoirs, Vol. i. p. 226.
‡ Ac. Par. 1737. M. p. 436.

PERIOD

PERIOD VI.

THE EXPERIMENTS OF DR. DESAGULIERS.

WE are now come to the labours of that indefatigable experimental philosopher Dr. DESAGULIERS, in this new field of science. The reason which he gives why he had avoided entertaining the Royal Society upon this subject before, and why he had not pursued it so far as he might have done; considering, as he says, that he could excite as strong an electricity in glass, by rubbing with his hand, as any body could, is worth mentioning for its curiosity, and for the light that it throws upon the temper and manner of Mr. Grey. He says, that he was unwilling to interfere with the late Mr. Stephen Grey, who had wholly turned his thoughts to electricity; but was of a temper to give it entirely over, if he imagined that any thing was done in opposition to him *.

DR. DESAGULIERS begins with observing very sensibly (and the observation is still true) that the phenomena of electricity are so odd, that, though we have a great many experiments upon that subject, we have not yet been able, from their comparison, to settle such a theory as will lead us to the cause of that property in bodies, or even to judge of

* Phil. Trans. abridged, Vol. viii. p. 419.

all

all its effects, or find out what useful influence electricity has in nature; though certainly, from what we have seen of it, we may conjecture that it must be of great use, because it is so extensive.

HIS first experiments, of which an account is given in the Philosophical Transactions, dated July, 1739, were made with a hempen string, extended upon cat-gut. To the end of the hempen string, he suspended various substances; and says, that all those which he tried, amongst which were several *electrics per se*, as sulphur, glass, &c. without exception, received electricity *.

HE changed one of the cat-gut strings, on which his hempen line of communication was extended, and put various other substances in its place, to try what bodies would transmit electricity to the suspended body, and what would not; and from the result of his experiments, partly concluded, that bodies in which electricity could not be excited intercepted the electric effluvia; and that those in which electricity could be excited, did not intercept it, but permitted it to go on to the extremity of the hempen string. But still he had no just idea, that, except metals, it was the moisture in the bodies he tried which intercepted the electric effluvia; and his ideas of the manner in which they were intercepted were very imperfect.

* Phil. Transf. abridged, Vol. viii. p. 420.

To Dr. Desaguliers we are indebted for some *technical terms* which have been extremely useful to all electricians to this day, and which will probably remain in use as long as the subject is studied. He first applied the term *conductor* to that body to which the excited tube conveys its electricity; which term has since been extended to all bodies that are capable of receiving that virtue. And he calls those bodies in which electricity may be excited, by heating or rubbing, *electrics per se*.

In the writings of this author we find many *axioms* relating to electrical experiments, some of which are expressed in a more clear, and distinct manner than they had been before; but the real improvements which he made, were very few and immaterial.

On several occasions, and particularly in a paper delivered to the Royal Society, in the month of January 1741, he lays down, among others, the following general rules, which seem to be more accurate than any which had been delivered before upon the subject *.

" An electric per se will not receive elec-
" tricity from another electric per se, in
" which it has been excited, so as to run
" along its whole length: but will only re-
" ceive it a little way, being, as it were, sa-
" turated with it.

* Phil. Trans. abridged, Vol. viii. p. 430.

" An

"AN electric per se will not lose all its "electricity at once, but only the electricity "of those parts near which a non-electric "has been brought. It, consequently, loses "its electricity the sooner, the more of those "bodies are near it. Thus, in moist weather, "the excited tube holds its virtue but a little "while, because it acts upon the moist va-"pours which float in the air. And if the "excited tube be applied to leaf gold laid "upon a stand, it will act upon it much "longer, and more strongly, than if the "same quantity of leaf gold be laid upon a "table, which has more non-electric surface "than the stand *." This, however, seems not to be the whole reason; for if the leaf gold were laid upon a broad surface of glass, it would not be acted upon so powerfully, as if it were placed upon a narrow stand of any kind of matter.

"A NON-ELECTRIC, when it has received "electricity, loses it all at once, upon the "approach of another non-electric." This however could only be the case when the approaching electric was not insulated, but had a communication with the earth. It must also be brought into contact with the electrified body.

"ANIMAL substances are non electrics by "reason of the fluids they contain †.

"EXCITED electricity exerts itself in a "sphere round the electric per se, or

* Phil. Transf. abridged, Vol. viii p. 427.
† Ibid p. 429.

 "rather

"rather in a cylinder, if the body be cylindrical *."

Few of the many experiments which were made by Dr. Desaguliers (accounts of which were published in the Philosophical Transactions) had, as I observed before, any thing new in them. Those which were the most so are the following.

Endeavouring to communicate electricity to a burning tallow candle, he observed, that the candle attracted the thread of trial, but not within two or three inches of the flame; but that, as soon as the candle was blown out, the thread was attracted by every part of it, and even by the wick, when the fire was quite extinguished. He electrified a wax candle in the same manner, and the experiment succeeded as well, only the electricity came not so near the flame in the wax, as in the tallow candle.

He says, that only warming a glass receiver, without any rubbing, would cause the threads of a down feather, tied to an upright skewer to extend themselves, as soon as it was put over the feather; and that sometimes rosin and wax would exert their electricity by being only exposed to the open air.

He observed that if a hollow glass tube, supporting the l ne of communication, were moistened by blowing through it, it would intercept the electricity.

* Phil. Transf. abridged, Vol. viii. p. 431.

He

He says, that when an excited tube has repelled a feather, it will attract it again, after being suddenly dipped into water, but in fair weather it will not attract it unless it hath been dipped pretty deep into the water, a foot of its length at least; whereas, in moist weather, an inch or two will suffice *.

He shewed the attraction of water by an excited tube, in a better manner than it had been shewn before, viz. by bringing the tube to a stream issuing from a condensing fountain: which, thereupon, was evidently bent towards it.

Dr. Desaguliers seems to have been the first who expressly said, that pure *air* might be ranked amongst electrics per se, and that cold air in frosty weather, when vapours rise least of all, is preferable, for electrical purposes, to warm air in summer, when the heat raises the vapours †. He also supposed that the electricity of the air was of the vitreous kind; and he accounted for the electricity appearing on the inside only of an exhausted glass vessel, by its going where it met with the least resistance from so electrical a body as the air ‡.

He endeavoured to account for the fixing of air by the steams of sulphur, according to the experiment of Dr Hales; by supposing that the particles of sulphur, and those of air, being possessed of different kinds of electricity, attracted one another, whereby their repulsive

* Phil. Trans. abridged, Vol. viii. p. 429.
† Ibid. p. 437. ‡ Ibid. 438.

power was deſtroyed. He alſo propoſed the following conjecture concerning the riſe of vapour. The air at the ſurface of water being electrical, particles of water, he thought, jumped to it, then, becoming themſelves electrical, they repelled both the air and one another, and conſequently aſcended into the higher regions of the atmoſphere *.

THE laſt paper of Dr. Deſaguliers in the Philoſophical Tranſactions, upon the ſubject of electricity, is dated June 24th, 1742, in which year he publiſhed a diſſertation on electricity, by which he gained the prize of the academy at Bourdeaux. This prize was a medal of the value of 300 livres, propoſed, at the requeſt of Monſieur Harpez de la Force, for the beſt eſſay on electricity, and ſhews how much this ſubject engaged the attention of philoſophers at that time †. The diſſertation is well drawn up, and compriſes all that was known of the ſubject till that period.

* Phil. Tranſ. abridged, Vol. viii. p. 437.
† Dantzick Memoirs, Vol. i. p. 261.

PERIOD

PERIOD VII.

EXPERIMENTS OF THE GERMANS, AND OF DR. WATSON, BEFORE THE DISCOVERY OF THE LEYDEN PHIAL IN THE YEAR 1746.

ABOUT the time that Dr. Deſaguliers had concluded his experiments in England, viz. 1742, ſeveral ingenious Germans began to apply themſelves to the ſame ſtudies with great aſſiduity, and their labours were crowned with conſiderable ſucceſs.

To the Germans we are indebted for many capital improvements in our electrical apparatus within this period, without which, the buſineſs would have gone on very ſlowly and heavily; but, by the help of their contrivances, we ſhall ſee that aſtoniſhing effects were ſoon produced,

MR. BOZE, a profeſſor of philoſophy at Wittemburgh, ſubſtituted the *globe* for the tube, which had been uſed ever ſince the time of Haukſbee*. He likewiſe added a *prime conductor*, which conſiſted of a tube of iron or tin, at firſt ſupported by a man ſtanding upon cakes of roſin, and afterwards ſuſ-

* According to other accounts, Chriſtian Auguſtus Hauſen, profeſſor of mathematics at Leipſic, was the firſt who revived the uſe of Haukſbee's glaſs globe, and Mr. Boze, who was excited to make experiments in electricity by the example of Mr. Hauſen, borrowed this capital improvement from him. Dantzick Memoirs, Vol. i. p. 278, 279.

pended on ſilk horizontally before the globe *.

To prevent the tube from doing any harm to the globe, he put a bundle of thread into the end which was next to it, and which was left open for that purpoſe. This expedient, beſides occaſioning various pleaſant phenomena, was obſerved to make the force of the conductor much ſtronger †.

THE uſe of the globe was immediately adopted in the univerſity of Leipſic, where Mr. Winckler, the profeſſor of languages, ſubſtituted a *cuſhion* inſtead of the hand, which had before been employed to excite the globe. But the beſt rubber for the globe, as well as the tube, was, long after this, ſtill thought, by all electricians, to be the human hand, dry, and free from moiſture ‡.

MR. P. GORDON, a Scotch Benedictine monk; and profeſſor of Philoſophy at Erford, was the firſt who uſed a *cylinder* inſtead of a globe. His cylinders were eight inches long, and four inches in diameter. They were made to turn with a bow, and the whole inſtrument was portable. Inſtead of a cake of roſin, he inſulated by means of a frame, furniſhed with net work of ſilk §.

THE apparatus, likewiſe, of many of the German electricians was very *various*, and expenſive. Mr. Winckler, in a paper read at the Royal Society, March 21ſt, 1745 ‖, de-

* Hiſtoire de l'electricité, p. 27.
† Phil. Tranſ. abridged, Vol. x. p. 271. ‡ Ibid. 272.
§ Hiſtoire, p. 31.
‖ Phil. Tranſ. abridged, Vol. x. p. 273.

ſcribes

ſcribes a machine for rubbing tubes, and another for rubbing globes, and compares the effects of them both. He obſerves, that the ſparks which are produced from glaſs veſſels drawn to and fro were larger, and more vehemently pungent, provided that thoſe veſſels were of the ſame magnitude with the globes; but that the flux of effluvia was not ſo conſtant as from the globes. Mr. Winckler alſo invented a machine, which he deſcribes at large in his works, by means of which he could give his globe ſix hundred and eighty turns in a minute *. This gentleman likewiſe contrived to rub glaſs, and china veſſels, in the inſide; and he ſays they acted as ſtrongly on bodies placed on the outſide of them, as when they were rubbed on the outſide †.

The German electricians generally uſed more globes than one at a time, and imagined they found the effects proportionable, though this fact was called in queſtion by Dr. Watſon, and others; and Mr. Nollet preferred globes made blue with zaffre ‡, which were carefully tried, and rejected by Dr. Watſon afterwards §.

Such a prodigious power of electricity could they excite from theſe globes, whirled by a large wheel, and rubbed with woollen cloth, or a dry hand (for we find both theſe methods were in uſe among them about this

* Hiſtoire, p. 32.
† Dantzick Memoirs, Vol. i. p. 400.
‡ In ſubſequent trials the Abbé himſelf found no advantage in theſe blue globes. Ac. Par. 1745. M. p. 162.
§ Phil. Tranſ. abridged, Vol. x. p. 277.

time)

time) that, if we may credit their own accounts, the blood could be drawn from the finger by an electric spark; the skin would burst, and a wound appear, as if made by a caustic. They say, that if several globes or tubes were used, the motion of the heart and arteries of the electrified person would be very sensibly increased; and that, if a vien were opened under the operation, the blood, issuing from it, would appear like lucid phosphorus, and run out faster than when the man was not electrified. Analogous to this last experiment, Mr. Gordon observed, that water, running from an artificial fountain electrified, was scattered in luminous drops, that a larger quantity of water was thrown out in a given time than when the fountain was not electrified *; and that electrified water evaporated faster than water not electrified, when exposed in similar glass vessels †. Part of this account we know might be true, but some part must have been exaggerated. It is certain that Mr. Gordon increased the electric sparks to such a degree, that they were felt from a man's head to his foot, so that a person could hardly take them without falling down with giddiness ‡, and small birds were killed by them §. This he effected by conveying electricity, with iron wires, to the distance of 200 ells from the place of excitation.

* Phil. Trans. abridged, Vol. x. p. 277.
† Dantzick Memoirs, Vol. ii. p. 357.
‡ Ibid. p. 358.
§ Nollet's Recherches, p. 172.

He

He alſo found that the ſparks were ſtronger when the wire was thick than when it was ſmall *.

Mr. Waitz made his glaſs tubes act ſtronger by rubbing them with a waxed cloth and a little oil. He alſo found, that glaſs made with very little pot-aſh, acted much better than that in the compoſition of which much of it was uſed; but it required longer time, and more heat to vitrify it. He got ſome glaſs made on purpoſe to aſcertain the fact †.

By various experiments of attraction and repulſion, which Mr. Waitz made in rubbing a dog (which he had made thoroughly dry for that purpoſe) he proved that the flaſhes of light, which ſometimes appear when animals are ſtroked, are electrical. This had been ſuppoſed, but was not accurately aſcertained before ‡. It was this gentleman who gained the prize of 50 ducats, propoſed, in the year 1744, by the Academy of Sciences at Berlin, for the beſt diſſertation on the ſubject of electricity. It was publiſhed along with three others, which were offered at the ſame time, and thought worthy of that honour §.

The thing that ſtrikes us moſt in their experiments, performed by theſe machines, is their ſetting fire to inflammable ſubſtances. This they were, probably, led to attempt, from obſerving the vivid appearance of elec-

* Dantzick Memoirs, Vol. ii. p. 359.
† Ibid. p. 381. ‡ Ibid. p. 385. § Ibid. p. 380.

tric light, the burning pain that was felt by a ſmart ſtroke from the conductor, and the many analogies the electric fluid evidently bore to phoſphorus and common fire.

THE firſt perſon who ſucceeded in this attempt was Dr. Ludolf of Berlin, towards the beginning the year 1744; who kindled, with ſparks excited by the friction of a glaſs tube, the etherial ſpirit of Frobenius. This he did at the opening of the Royal Academy, and in the preſence of ſome hundreds of perſons. He performed the experiment by electric ſparks proceeding from an iron conductor. Mr. Winckler did the ſame in the May following, by a ſpark from his own finger; and kindled, not only the highly rectified ſpirit above-mentioned, but French brandy, corn ſpirits, and other ſpirits ſtill weaker, by previouſly heating them. He alſo ſays, that oil, pitch, and ſealing-wax might be lighted by electric ſparks, provided thoſe ſubſtances were firſt heated to a degree next to kindling *. To theſe it muſt be added, that Mr. Gralath fired the ſmoke of a candle juſt blown out, and lighted it again †; and that Mr. Boze fired gunpowder, melting it in a ſpoon, and firſt the vapour that roſe from it.

THE German electricians, likewiſe, conſtructed a machine, by which they could give friction to a glaſs cylinder in vacuo. By theſe means they contrived to electrify a wire which terminated in the open air, and there ſhewed

* Phil. Tranſ. abridged, Vol. x. p. 271.
† Dantzick Memoirs, Vol. ii. p. 438.

a con-

a confiderable electric power. They alfo electrified that end which was in the open air, and made the other end which was in vacuo exert its electricity *.

THE fame Germans alfo mention an experiment, which, if purfued, would have led them to difcover, that the friction of the glafs globe did not produce, but only collect the electric matter. But that was a difcovery referved, as we fhall find, for Dr. Watfon. It feems that both Mr. Boze and Mr. Allamand had fufpended the machine, and the man who worked it, upon filk; and obferved, that, not only the conductor, but alfo the man, and the machine gave figns of electricity; though they did not attend accurately to all the circumftances of that curious fact, which did not at all anfwer their expectations. For, imagining that part of the electric power was continually going off to the ground by the machine, they fuppofed that the effect of infulating it, would have been a ftronger electricity †.

IN this period it was that Ludolf the younger demonftrated, that the luminous barometer is made perfectly electrical by the motion of the quickfilver; firft attracting, and then repelling bits of paper, &c. fufpended by the fide of the tube, when it was enclofed in another out of which the air was extracted ‡. Before this experiment, thofe ef-

* Phil. Tranf. abridged, Vol. x. p. 275.
† Wilfon's Effay, preface, p. 14. Watfon's Sequel, p. 34.
‡ Dantzick Memoirs, Vol. iii. p. 495.

fects

fects had been aſcribed to the air *. Profeſſor Hamberger and Mr. Waitz had diſcovered that the motion of quickſilver in a glaſs veſſel, out of which the air was extracted, had the power of moving light bodies; and Mr. Allamand likewiſe found, that it made no difference whether the veſſel had air in it or not †.

About the ſame time alſo, Mr. Boze took a great deal of pains to determine, whether the weight of bodies would be affected by electricity, but he could not find that it was.

The electrical *ſtar*, made by turning ſwiftly round an electrified piece of tin, cut with points equidiſtant from the center; and alſo the *electrical bells*, which will be deſcribed hereafter among the ſurpriſing and diverting experiments performed by the help of electricity, were of German invention ‡. The ſtar was contrived by Mr. Gordon, and by turning the points a little obliquely, he was ſurpriſed to find it began to move of itſelf §. Laſtly, to theſe it may be added, that Mr. Winckler contrived a wheel to move by electricity; that Mr. Boze conveyed electricity from one man to another by a jet of water, when they were both placed upon cakes of roſin, at the diſtance of ſix paces; and that Mr. Gordon even fired ſpirits by a jet of water ‖.

* Hiſtoire, p 89.
† Dantzick Memoirs, Vol. ii. p. 426.
‡ Nollet's Recherches, p. 187.
§ Dantzick Memoirs, Vol. ii p. 317, 358.
‖ Phil. Tranſ. abridged, Vol. x. p. 276.

Mr.

MR. GOTTFRIED HEINRICK GRUMMERT, of Biala in Poland, made a curious experiment upon electric light, which, as we ſhall ſee, was afterwards made and purſued to great advantage by Dr. Watſon and Mr. Canton. In order to obſerve whether an exhauſted tube would give light when it was electrified, as well as when it was excited, he preſented one, eight inches long, and a third of an inch wide, to the electrified conductor, and was ſurpriſed to find the light dart very vividly the whole length of the tube. He alſo obſerved, that, ſome time after the tube had been preſented to the conductor, and expoſed to nothing but the air, it gave light again, without being brought to any electrified body. This light *in vacuo* Mr. Grummert propoſed to make uſe of in mines and places, where common fires, and other lights cannot be had, and for this purpoſe he mentions ſeveral methods of increaſing this light *.

I SHALL conclude this account of the diſcoveries of the German Philoſophers in this period with a very curious one of profeſſor Kruger, concerning the change made in the colour of bodies by the electric effluvia. In order to try, whether there was any thing of ſulphur in theſe effluvia, he expoſed the red leaves of wild poppies to the electric ſpark, and found that they were preſently changed to white. He was not able to produce any change in yellow colours, nor in

* Dantzick Memoirs, Vol. i. p. 417.

blue

blue immediately; but found that when they had lain a day or two, after being exposed to this operation they became white. In these experiments the leaves were fastened with white wax to plates of tin *.

SUCH a general attention was excited to electricity by these curious discoveries, that, in the year 1745, electrical experiments were exhibited, in Germany and Holland, for money, as a show; and public advertisements appeared in the news-papers for that purpose †.

The firing of the effluvia of bodies, which was first done in Germany, was soon after repeated in England, and among others by Dr. Miles; who, as appears by a paper of his, read at the Royal Society, March the 7th, 1745, kindled phosphorus by the application of the excited tube itself to it without the intervention of any conductor ‡.

THIS gentleman's tube happening to be in excellent order upon this occasion, he observed, and was perhaps the first who observed, *pencils of rays*, which he calls *coruscations*, darting from the tube, without the aid of any conductor approaching it. Of these coruscations he gave a drawing, which answers pretty exactly to the appearance of such pencils as are now very common, particularly since Mr. Canton has taught us the use of the amalgama, by which a tube may be excited

* Dantzick Memoirs, Vol. iii. p. 393.
† Ibid. Vol. ii. p. 399.
‡ Phil. Transf. abridged, Vol. x. p. 272.

much

much more ſtrongly than it could have been before *.

BUT the moſt diſtinguiſhed name in this period of the hiſtory of electricity, is that of Dr. WATSON. He was one of the firſt among the Engliſh who took up, and improved upon, the diſcoveries made by the Germans; and to his ingenuity, and intenſe application, we owe many curious improvements and diſcoveries in electricity. His firſt letters to the Royal Society on this ſubject are dated between March 28th, and October 24th, 1745.

DR. WATSON's attention to the ſubject of electricity ſeems firſt, or principally, to have been engaged by the accounts of the Germans having fired ſpirit of wine by it. In this experiment he ſucceeded; and, moreover, found that he was able to fire, not only the ethereal ſpirit of Frobenius, and rectified ſpirit of wine, but even common proof ſpirit. He alſo fired air made inflammable by a chemical proceſs †. He even fired both ſpirit of wine, and inflammable air, by a drop of cold water, thickened with a mucilage made with the ſeed of flea-wort, and even with ice ‡. He alſo fired theſe ſubſtances with a hot poker electrified, when it would not fire them in any other ſtate §. He fired gunpowder and diſcharged a muſket by the power of electricity, when the gunpowder had been ground with a little camphor, or a few drops of ſome

* Phil. Tranſ. abridged, Vol. x. p. 272.
† Ibid. p. 286. ‡ Ibid. p. 290. § Ibid. p. 288.

inflammable chemical oil *. Laſtly, it was a diſcovery of Dr. Watſon's, that theſe ſubſtances were capable of being fired by what he calls *the repulſive power of electricity*; which was performed by the electrified perſon holding the ſpoon which contained the ſubſtance to be fired, and another perſon, not electrified, bringing his finger to it †. Before this time, the ſubſtance to be fired had always been held by a perſon not electrified.

In his attempts to fire electrics per ſe, as turpentine, and balſam of capivi, by this repulſive power, he thought he confuted an opinion which had prevailed among many perſons, that electricity only floated on the ſurfaces of bodies, for he found that the fume of theſe ſubſtances could not be fired by a ſpark fetched from the ſpoon which contained them. This ſpark muſt therefore paſs through the electric, from the ſurface of the ſpoon below, which was in contact with the electrified conductor.

Electrifying a number of pieces of fine ſpun glaſs, and other pieces of wire, of the ſame length and thickneſs, he was agreeably amuſed by obſerving, that the threads of glaſs jumped to the electrified body, and adhered to it without any ſnapping; whereas the wires jumped up and down very faſt, giving a ſnap, and a ſmall flame, every time ‡.

* Phil. Tranſ. abridged, Vol. x. p. 289.
† Ibid. p. 281. ‡ Ibid. p. 286.

IN a paper read at the Royal Society, February 6th, 1746, he obſerved, that electric ſparks appeared different in colour and form, according to the ſubſtances from which they proceeded; that the fire appeared much redder from rough bodies, as ruſty iron, &c. than from poliſhed bodies, though they were ever ſo ſharp, as from poliſhed ſciſſars, &c. He judged that the different appearance was owing rather to the different reflection of the electric light from the ſurface of the bodies from which it was emitted, than to any difference in the fire itſelf *.

He alſo obſerved, that electricity ſuffered no refraction in pervading glaſs; having found, by exact obſervations, that its direction was always in right lines, even through glaſſes of different forms, included one within another, and large ſpaces left between each glaſs †; that if books or other non-electrics were laid upon glaſs and interpoſed between the excited electric and light bodies, the direction of the virtue was ſtill in right lines, and ſeemed inſtantly to paſs through both the books and the glaſs. In theſe experiments he conſtantly obſerved, that the electric attraction through glaſs was much more powerful when the glaſs was made warm than when it was cold ‡. He ſometimes found electricity to pervade, though in ſmall quantities, electrics of above four inches thick §.

* Phil. Tranſ. abridged, Vol. x. p 2-0. † Ibid. p. 291.
‡ Ibid. p. 292. § Ibid. p. 295.

He says, that in electriying substances of great extent, the attractive power was first observed at that part of it which was most remote from the excited electric.

He made some experiments which showed, that the fire of electricity was affected, neither by the presence, nor the absence of other fire. One of his experiments was made with a chemical mixture, thirty degrees below the freezing point of Fahrenheit's thermometer; from which, when electrified, the flashes were as powerful, and the strokes as smart, as from red hot iron *.

In a sequel to the above experiments, read the 30th of October 1746, Dr. Watson mentions his having lined a glass globe to a considerable thickness with a mixture of wax and rosin; but he found no difference between that and the other globes †.

He also made various experiments with a number of globes, whirled at the same time, and having one common conductor; and concluded from them, that the power of electricity was increased by the number and size of the globes, to a certain degree, but by no means in proportion to their number and size. Yet the Doctor allows a very great increase, in an inference he makes from these very experiments. As bodies to be electrified, he says, will only contain a certain quantity of electricity; when that quantity is acquired, *which is soonest done by a number of globes*, the

* Phil. Transf. abridged, Vol. x. p. 293.
† Ibid. p. 295.

surcharge

ſurcharge is diſſipated as faſt as it is excited So that, it is plain, more fire was collected by the number of globes, though the form of the conductor he made uſe of was ſuch as could not retain it. The great power of his four globes united, is manifeſt from his own account of them. For, he ſays, that when two pewter plates were held, one in the hand of an electrified perſon, and the other in the hand of one who ſtood upon the floor; the flaſhes of pure and bright flame were ſo large, and ſucceeded each other ſo faſt, that, when the room was darkened, he could diſtinctly ſee the faces of thirteen perſons who ſtood round the room *.

Lastly, the Doctor found, that the ſmoke of original electrics was a conductor of electricity, and alſo that flame would conduct the whole of it undiminiſhed; by obſerving that two perſons, ſtanding upon electrics, could communicate the virtue to each other, with nothing interpoſed but the ſmoke in the one caſe, and flame in the other †.

It was in this period that Mr. Du Tour diſcovered that flame would deſtroy electricity; as he informed the Abbé Nollet, in a letter dated 21ſt Auguſt 1745. The ſame was alſo diſcovered by Mr. Waitz.

* Phil. Tranſ. abridged, Vol. x. p. 295.
† Ibid. p. 296.

PERIOD VIII.

THE HISTORY OF ELECTRICITY, FROM THE DISCOVERY OF THE LEYDEN PHIAL IN THE YEARS 1745 AND 1746, TO DR. FRANKLIN'S DISCOVERIES.

SECTION I.

THE HISTORY OF THE LEYDEN PHIAL ITSELF, TILL DR. FRANKLIN'S DISCOVERIES RELATING TO IT.

THE end of the year 1745, and the beginning of 1746 were famous for the most surprising discovery that has yet been made in the whole business of electricity, which was the wonderful accumulation of its power in glass, called at first the LEYDEN PHIAL; because made by Mr. Cuneus a native of Leyden, as he was repeating some experiments which he had seen with Messrs. Muschenbroeck, and Allamand, professors in the university of that city *. But the person who first made this great discovery, was Mr. Von Kleist, dean of the cathedral in Camin; who, on the 4th of November 1745, sent an account of it to Dr. Lieberkuhn at Berlin. This account, as taken by Mr. Gralath out

* Dalibard's Histoire abrigée, p. 33.

of

of the regiſter of the academy at Berlin, to which it had been communicated, is as follows. "When a nail, or a piece of thick "braſs wire, &c. is put into a ſmall apothe-"cary's phial and electrified, remarkable "effects follow: but the phial muſt be very "dry, or warm. I commonly rub it over "before-hand with a finger, on which I put "ſome pounded chalk. If a little mercury "or a few drops of ſpirit of wine, be put "into it, the experiment ſucceeds the better. "As ſoon as this phial and nail are removed "from the electrifying glaſs, or the prime "conductor, to which it hath been expoſed, "is taken away, it throws out a pencil of "flame ſo long, that, with this burning ma-"chine in my hand, I have taken above ſixty "ſteps, in walking about my room. When "it is electrified ſtrongly, I can take it into "another room, and there fire ſpirits of wine "with it. If while it is electrifying, I put "my finger, or a piece of gold, which I "hold in my hand, to the nail, I receive a "ſhock which ſtuns my arms and ſhoulders.

"A TIN tube, or a man, placed upon "electrics, is electrified much ſtronger by this "means than in the common way. When "I preſent this phial and nail to a tin tube, "which I have, fifteen feet long, nothing but "experience can make a perſon believe how "ſtrongly it is electrified. I am perſuaded, "he adds, that, in this manner, Mr. Boze "would not have taken a ſecond electrical "kiſs. Two thin glaſſes have been broken

"by the ſhock of it. It appears to me very "extraordinary, that when this phial and nail "are in contact with either conducting or "non-conducting matter, the ſtrong ſhock "does not follow. I have cemented it to "wood, metal, glaſs, ſealing-wax, &c. when "I have electrified without any great effect. "The human body, therefore, muſt contri- "bute ſomething to it. This opinion is con- "firmed by my obſerving, that, unleſs I hold "the phial in my hand, I cannot fire ſpirits "of wine with it *."

NOTWITHSTANDING Mr. Kleiſt immediately communicated an account of this famous experiment (which indeed it is evident he has but imperfectly deſcribed) to Mr. Winckler at Leipſick, Mr. Swiettiki of Dantzick, Mr. Kruger of Hall, and to the profeſſors of the academy of Lignitz, as well as to Dr. Lieberkuhn of Berlin above-mentioned, they all returned him word, that the experiment did not ſucceed with them. Mr. Gralath of Dantzick, was the firſt with whom it anſwered; but this was not till after ſeveral fruitleſs trials, and receiving farther inſtructions from the inventor †.

THE Abbé Nollet had information of this diſcovery, and, in conſequence of it, ſays, in a letter to Mr. Samuel Wolfe, of the Society of Dantzick, dated March 9th, 1746, that the experiment at Leyden was upon principles ſimilar to this made with a phial half full of

* Dantzick Memoirs, Vol. i. p. 407. † Ibid. p 411.

water,

water, and a nail dipped in it; and that this discovery would have been called the Dantzick experiment, if it had not happened to have got the name of that of Leyden *.

THE views which led to this discovery in Holland were, as I have been informed, as follows. Professor Muschenbroeck and his friends, observing that electrified bodies, exposed to the common atmosphere, which is always replete with conducting particles of various kinds, soon lost their electricity, and were capable of retaining but a small quantity of it, imagined, that, were the electrified bodies terminated on all sides by original electrics, they might be capable of receiving a stronger power, and retaining it a longer time. Glass being the most convenient electric for this purpose, and water the most convenient non-electric, they first made these experiments with water, in glass bottles: but no considerable discovery was made, till Mr. Cuneus, happening to hold his glass vessel in one hand, containing water, which had a communication with the prime conductor, by means of a wire; and, with the other hand, disengaging it from the conductor (when he imagined the water had received as much electricity as the machine could give it) was surprised by a sudden shock in his arms and breast, which he had not in the least expected from the experiment.

* Dantzick Memoirs, Vol. i p. 409.

MR. ALLAMAND and Mr. Muſchenbroeck were the firſt who repeated and publiſhed an account of this experiment in Holland, the Abbé Nollet and Monſieur Monnier in France, and Meſſrs. Gralath and Rugger in Germany *.

IT is extremely curious to obſerve the deſcriptions which philoſophers, who firſt felt the electrifical ſhock, give of it; eſpecially as we are ſure we can give ourſelves the ſame ſenſation, and thereby compare their deſcriptions with the reality. Terror and ſurprize certainly contributed not a little to the exaggerated accounts they gave of it; and, could we not have repeated the experiment, we ſhould have formed a very different idea of it from what it really is, even when given in greater ſtrength than thoſe who firſt felt this electrical ſhock were able to give it. It will amuſe my readers if I give them an example or two.

MR. MUSCHENBROECK, who tried the experiment with a very thin glaſs bowl, ſays, in a letter to Mr. Reaumur, which he wrote ſoon after the experiment, that he felt himſelf ſtruck in his arms, ſhoulder and breaſt, ſo that he loſt his breath, and was two days before he recovered from the effects of the blow and the terror. He adds, that he would not take a ſecond ſhock for the kingdom of France †.

* Dantzick Memoirs, Vol ii. p. 433.
† Hiſtoire, de l'electricité, p. 30.

THE

THE first time Mr. Allamand made this experiment (which was only with a common beer glaſs) he ſays, that he loſt the uſe of his breath for ſome moments; and then felt ſo intenſe a pain all along his right arm, that he at firſt apprehended ill conſequences from it, though it ſoon after went off without any inconvenience *. But the moſt remarkable account is that of Mr. Winckler of Leipſic. He ſays, that the firſt time he tried the Leyden experiment, he found great convulſions by it in his body; and that it put his blood into great agitation; ſo that he was afraid of an ardent fever, and was obliged to uſe refrigerating medicines. He alſo felt an heavineſs in his head, as if a ſtone lay upon it. Twice, he ſays, it gave him a bleeding at his noſe, to which he was not inclined. His wife (whoſe curioſity, it ſeems, was ſtronger than her fears) received the ſhock only twice, and found herſelf ſo weak, that ſhe could hardly walk; and, a week after, upon recovering courage to receive another ſhock, ſhe bled at the noſe after taking it only once †.

WE are not, however, to infer from theſe inſtances, that all the electricians were ſtruck with this panic. Few, I believe, would have joined with the cowardly profeſſor, who ſaid that he would not take a ſecond for the kingdom of France. Far different from theſe were the ſentiments of the magnanimous Mr. Boze, who with a truly philoſophical heroiſm, worthy

* Phil. Tranſ. abridged, Vol. x. p. 321.
† Ibid. p. 327.

of

of the renowned Empedocles, said he wished he might die by the electric shock, that the account of his death might furnish an article for the memoirs of the French Academy of Sciences *. But it is not given to every electrician to die in so glorious a manner as the justly envied Richman.

It was this astonishing experiment that gave eclat to electricity. From this time it became the subject of general conversation. Every body was eager to see, and, notwithstanding the terrible account that was reported of it, to *feel* the experiment; and in the same year in which it was discovered, numbers of persons, in almost every country in Europe, got a livelihood by going about and showing it.

While the vulgar of every age, sex, and rank were viewing this prodigy of nature and philosophy with wonder and amazement, we are not surprized to find all the electricians of Europe immediately employed in repeating this great experiment, and attending to the circumstances of it. Mr. Allamand remarked, that, when he first tried it, he stood simply upon the floor, and not upon cakes of rosin. He said, that it did not succeed with all kinds of glass; for that, though he had tried several, he had perfect success with none but that of Bohemia, and that he had tried English glasses without any effect at all †. Professor Muschenbroeck at that time only

* Histoire, p. 164.
† Phil. Transf. abridged, Vol. x. p. 321.

observed,

observed, that the glass must not be all wet on the outside.

It is no wonder that so few of the properties of glass charged with electrical fire were known at first, notwithstanding the attention that was immediately given to the subject by all the electricians in Europe. The experiment is, to this day, justly viewed with astonishment by the most profound electricians: for, though some remarkable phenomena of it have been excellently accounted for by Dr. Franklin, and others, much remains to be done; and, in many respects, the circumstances attending it are still inexplicable. What will result from more attention being given to it, time only can show.

To begin the farther illustration of this discovery with such of the phenomena as were observed in Germany, where it was made. Mr. Gralath made the shock much stronger by using a glass vessel five inches in diameter, with a narrow neck, ten inches long; by substituting an iron wire with a knob of tin for the iron nail, and water for spirit of wine*. He first found, that the same shock could be communicated to a number of persons, who took hold of one another's hands; if the person at one extremity of the line they made, touched the outside of the phial, and he at the other touched a wire communicating with the inside. In this manner, on the 10th of April, 1746, he gave

* Dantzick Memoirs, Vol. ii. p. 411.

a shock

a ſhock to twenty perſons; and he ſays, he did not doubt, but it might be given to a thouſand *. When theſe perſons were connected by pieces of metal, and did not hold one another's hands, they found the ſame ſhock, but not when they held wood, and other imperfect conductors †. This gentleman, alſo, gave a ſhock, by means of long wires, to a perſon ſtanding in a garden, while he himſelf, who directed the experiment, had the machine in a part of the houſe at a conſiderable diſtance ‡; and he was the firſt who made what we now call an *electrical battery*; for he increaſed the ſhock by charging ſeveral phials at the ſame time §. Laſtly he obſerved that if the phial had the leaſt crack in it, it could never give a ſhock; and alſo that when a phial was diſcharged it acquired a ſmall charge by ſtanding, without receiving any thing from the machine, ſo as to give a ſmall ſhock ‖. This is what we now call the *reſiduum* of a charge, and is properly that part of the charge that lay on the uncoated part of the phial, which doth not let go all its electricity at once; ſo that it is, afterwards, gradually diffuſed to the coating.

MR. WINCKLER found out the method of making the diſcharge of the phial without feeling the ſhock himſelf, by not bringing his own body into the direct circuit ¶. He alſo gave the ſhock when ſeveral ells of run-

* Dantzick Memoirs, Vol. ii. p. 439. † Ibid. p. 440.
‡ [illegible] § Ibid. p. 552.
‖ [illegible] p. 514, 516. ¶ Ibid. Vol. ii. p. 459.

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ning water, in his garden, made part of the circuit. This he did on the 28th of July 1746, about the same time that Monsieur Monnier performed the same experiment in France*. And, lastly, he found, that the more globes were used, and the larger they were, the stronger was the shock†. This must be the consequence of increasing the power of excitation.

When Mr. Jallabert made the Leyden experiment with hot water, the phial broke by a spontaneous discharge, and a circular piece, two lines and a half in diameter, was thrown from the place of the rupture, against a wall, which was at the distance of five feet. The vessel, he says, had no crack, or other injury‡.

Dr. Watson, who gives an account of this famous experiment in the Philosophical Transactions, observes, that it succeeded best when the phial, which contained the water, was of the thinnest glass, and the water warmer than the ambient air. He says he tried the effect of increasing the quantity of water in glass vessels of different sizes, as far as four gallons, without in the least increasing the stroke. He also observed, that the force of the stroke did not increase in proportion to the size of the globe, or the number of globes employed upon the occasion; for that he had been as forcibly struck with a phial

* Dantzick Memoirs, Vol. iii. p. 504.
† Ibid. p. 526. ‡ Jallabert's Experiences, p. 128.

charged

charged by means of a globe of ſeven inches in diameter, as from one of ſixteen, or from three of ten; and that, at Hamburgh, a ſphere had been employed of a Flemiſh ell in diameter, without the expected increaſe of power. But, in both theſe obſervations, there muſt have been ſome miſtake. He found, that if mercury was uſed inſtead of water, the ſtroke was by no means increaſed in proportion to its ſpecific gravity. He alſo firſt obſerved, that ſeveral men, touching each other, and ſtanding upon electrics, were all ſhocked, though only one touched the gun barrel; but that no more fire was viſible from them all, than if one had only diſcharged it.

Several of theſe obſervations ſhow how imperfectly this great experiment was underſtood, for ſome time after it was firſt made. Dr. Watſon, however, obſerved a circumſtance attending the charging of the phial, which, if purſued, would have led him to the diſcovery, which was afterwards made by Dr. Franklin. He ſays, that "when the phial is well electrified, and you apply your hand thereto, you ſee the fire flaſh from the outſide of the glaſs, wherever you touch it, and it crackles in your hand *."

He alſo obſerved, that when a ſingle wire only was faſtened round a phial, properly filled with warm water, and charged; upon the inſtant of its exploſion, the electrical corruſcations were ſeen to dart from the wire,

* Philoſophical Tranſactions abridged, Vol. x. p. 298.

and

and to illuminate the water contained in the phial.

SEVERAL other very important circumstances, relating to the discharge of the phial, were observed by Dr. Watson. He found that the stroke was, *cæteris paribus*, as the points of contact of the non-electrics on the outside of the glass. And upon showing Dr. Bevis the experiments which proved this assertion, the Doctor suggested a more clear and satisfactory method of proving it, and which has been the means of accumulating and increasing the force of charged glass, far beyond what was expected from the first discovery of it. This method was, *coating* the outside of the phial, very near to the neck, with sheet-lead, or tinfoil. When a bottle was prepared in this manner, and nearly filled with water, they observed, that a person who only held in his hand a small wire communicating with that coating, felt as strong a shock as he would have felt, if his hand had been in actual contact with every part of the phial touched by the coating *.

DR. WATSON also discovered, that the electrical power, in the discharge of the phial, darts *rectissimo cursu*, as he styles it, between the gun-barrel and the phial; and, though it is not strictly true, that the shock goes the nearest way, yet it does so *cæteris paribus*, which alone was a considerable discovery for that time. He observed, that, in a company

* Phil. Transf. abridged, Vol. x. p. 299.

joining hands, a person touching two other persons in the circle, who did themselves touch one another, felt nothing of the shock, his body making no necessary part of the circle; and also, if a man, holding a wire, which communicated with the outside of the phial, as it hung upon the conductor, should touch the conductor with it; the explosion was made, but the man felt nothing *.

In a paper read at the Royal Society, January 21st, 1748, Dr. Watson mentions another discovery relating to the Leyden phial, which Dr. Bevis suggested, and he completed. Having been before fully satisfied, that the shock from the phial was not in proportion to the quantity of matter contained in the glass, but was increased by it, and likewise by the number of points of non-electric contact on the outside of the glass; he procured three jars, into which he put round leaden shot, and, joining their wires and coating, discharged them all as one jar. Upon this he observed, that the electrical explosion from two or three of those jars was not double or treble to that from one of them; but that the explosion from three was much louder than that from two, and the explosion from two much louder than that from one †.

This experiment had induced him to imagine, that the explosion from those jars was owing to the great quantity of non-electric matter contained in them. And whilst he was

* Phil. Transf. abridged, Vol. x. p. 301.
† Ibid. p. 374.

consider-

confidering of fome certain method of affuring himfelf whether the fact was fo, Dr. Bevis informed him, that he had found the electrical explofion to be as great from covering the fides of a pane of glafs, within about an inch of the edge (which was a curious improvement of Mr. Smeaton's), as it could have been from an half pint phial of water. Upon this Dr. Watfon coated large jars with leaf filver, both infide and outfide, within an inch of the top, and from the great expofion he produced, when fo little non-electric matter was contained in them, he was of opinion, that the effect of the Leyden bottle was greatly increafed by, if it was not principally owing to, not fo much the quantity of non-electric matter contained in the glafs, as the number of points of non-electric contact within the glafs, and the denfity of the matter of which thofe points confifted; provided the matter was, in its own nature, a ready conductor of electricity. He alfo obferved, that the explofion was greater from hot water inclofed in glaffes, than from cold; and from his coated jars warmed, than when cold *.

THE Doctor obferved, that when the circle for the difcharge was not through perfect conductors, the explofion was made flowly, and not all at once. This law, he fays, was invariable, but he was not able to account for it. But to prove that the electricity paffed with its whole force through the circle of

* Phil. Tranf. abridged, Vol. x. p. 377.

non-electrics, he made a circuit consisting of iron bars, and spoons filled with spirits between each bar (but at some small distance from them), and, upon the explosion, all the spoons were on fire at once. This was the first time, as he observes, that spirits were fired without either the spirits, or the non-electric on which they were placed, being insulated, or put upon original electrics. And yet, he says, though we know, from its effects, that the electricity goes through the whole circuit of non-electrics, with all its vigour, its progress is so quick, as not to affect, by attracting or otherwise, any light bodies disposed very near the non-electrics, through which it must necessarily pass *.

It is curious to observe in what manner Dr. Watson explained the shock of the Leyden phial, about the time that he first made the experiment with it. He had then been led (by a course of experiments which will be mentioned hereafter) to the notion both of the *afflux*, and *efflux* of electric matter in all electrical experiments. To apply this principle to the case in hand, he supposed, that the man who felt the shock parted with as much of the fire from his body, as was accumulated in the water and the gun-barrel; and that he felt the effect in both arms, from the fire which was in his body, rushing through one arm to the gun barrel, and through the other to the phial. He imagined also, that as much

* Phil. Transf. abridged, Vol. x. p. 378.

fire as the man parted with was inſtantly replaced from the floor of the room, and that with a violence equal to the manner in which he loſt it. It alſo appears, from Dr. Watſon's remarks on ſome ſubſequent experiments of Mr. Monnier, that he then imagined, that though a conſiderable quantity of the electric matter pervaded the glaſs (as he thought was ſeen upon preſenting a non-electric body to it, when it ſtood upon the glaſs ſtand, and without which it could not be charged at all) yet, that the loſs of the electric matter this way was not equal to what came in by the wire; the thinneſs of the glaſs permitting it not wholly, but partially to ſtop the electricity *.

Afterwards, when (from a courſe of experiments, which will alſo be recited in their proper place) Dr. Watſon changed his opinion about this afflux and efflux of electric matter, with a generoſity and frankneſs becoming every inquirer after truth, he retracted this hypotheſis; and, in refutation of it, he farther adds, that the charged phial will explode with equal violence, if the hoop of the wire be bent, ſo as to come near the coating of the phial, without any other non-electric body being near, from which ſuch a quantity could be ſupplied. He had alſo obſerved, that if a man ſtood upon glaſs, and diſcharged the phial, he felt the ſame ſhock as if he had ſtood upon the floor. I ſhall ſub-

* Phil. Tranſ. abridged, Vol. x. p. 348.

join a remarkable paragraph of the Doctor himself upon this occasion, as I think it very applicable even to us, in this more advanced state of the science.

"I TAKE notice of these," says the Doctor, "in as much as, notwithstanding the "very great progress which has been made "in our improvements in this part of natural "philosophy, within these few years; poste- "rity will regard us as only in our *noviciate*; "and therefore it behoves us, as far as we "can be justified therein by experiment, to "correct any conclusions we may have "drawn, if others yet more probable present "themselves *." The Doctor has lived to see, not only that *posterity* would consider him and his assistants at that time, as in their noviciate; but he *himself*, already in the course of a few years, looks upon both himself and them in the same light. And, considering the quick advances still making in this science, it is to be hoped he may still live to see, even the electricians of the present year to have been only in their noviciate.

HAVING seen what was done by Dr. Watson towards explaining the electric shock, before it was undertaken by Dr. Franklin; let us see what obligations we are under to other English electricians, and particularly Mr. Wilson.

MR. WILSON says that, as early as the year 1746, he discovered a method of giving

* Phil. Transf. abridged, Vol. x. p. 373.

the ſhock to any particular part of the body without affecting the reſt *. He increaſed the ſtrength of the ſhock by plunging the phial in water, thereby giving it a coating of water on the outſide, as high as it was filled on the inſide †.

In a letter to Mr. Smeaton, dated Dublin October 6th, 1746, he mentions his having made ſome experiments, in order to diſcover the law of accumulation of the electric matter in the Leyden bottle; and found, that it was always in proportion to the thinneſs of the glaſs, the ſurface of the glaſs, and that of the non-electrics in contact with the inſide and outſide thereof. The experiments, he ſays, were made with water a little warmed, which was poured into the bottle, while the outſide was immerged in a veſſel filled with water, but a little colder; leaving three inches, or thereabout, uncovered, which was preſerved dry and free from duſt. An account of this experiment he wrote to Mr. Folkes, and it was read before the Royal Society, October 23d, 1746, as appears by their minutes of that day, though the original was loſt or miſlaid.

Another curious experiment Mr. Wilſon made, in order to prove an hypotheſis, which he conceived very early, of the influence of a ſubtle medium ſurrounding all bodies, and reſiſting the entrance or exit of the electric fluid. To determine this, he made

* Wilſon's Eſſay, p. 83. † Ibid. p. 71.

the Leyden experiment with a chain, and considered each link of it as having two surfaces, at least; so that lengthening or shortening the chain, in each experiment, would occasion different resistances; and the event, he says, proved accordingly. When he made the discharge with one wire only, he found the resistance to be less than when a chain was used. But to leave no room for doubt, he caused the chain to be stretched with a weight, that the links might be brought nearer into contact, and the event was the same as when a single wire had been used *.

Two circuits being made, one consisting of the arms of a man, and the other of the links of a chain; he found, that the fire would take the arms of the man; but that if the chain were stretched, it would take the chain. No person, he says, who has not made the experiment, would imagine, with how much force the chain must be stretched before the experiment will answer, and the electric fluid pass through it without producing a spark at any of the links; that is, before the links can be brought into absolute contact with one another, their own weight being by no means sufficient †.

MR. WILSON observed, that if one part of the Leyden phial wss ground very thin, and covered with sealing-wax till it was charged, and then had the sealing-wax taken off, and a conductor communicating with the earth

* Letter to Hoadley. † Wilson and Hoadley, p. 65.

touched the thin part, the charge would be diſſipated in nearly half the time that it otherwiſe would have been *.

He obſerved that bodies, placed without the electric circuit, would be affected with the ſhock, if they were only in contact with any part of it, or very near it. To ſhew this to the moſt advantage, he ſet a charged phial upon a glaſs ſtand, and placed ſeveral pieces of braſs upon the ſtand, one of them in contact with the chain that formed the circuit, and others a twentieth of an inch from it, or from one another; and, upon making the diſcharge, there was a ſpark viſible between each of them †.

Analogous, in ſome reſpects, to this, was Mr. Wilſon's obſervation, that if the circuit was not made of metals, or other very good conductors, the perſon who laid hold of them, in order to perform the experiment, felt a conſiderable ſhock in that arm which was in contact with the circuit.

He alſo obſerved, that when the phial was coated, within and without, with metals, the firſt exploſion bore the greateſt proportion to the ſubſequent ones, the whole charge being diſſipated almoſt at once; whereas, when water was uſed, the ſubſequent exploſions were more in number, and more conſiderable; and that when the phial was charged with nothing but a wire inſerted into it, the firſt exploſion

* Wilſon's Eſſay, p. 74. † Ibid. p. 90.

and the subsequent ones were still more nearly equal.

MR. WILSON once happening to break a small wire by the convulsive shock given to his arms by the Leyden phial, he fastened to his hands, well guarded with leather, a large wire, of the thickness of a slender knitting needle, and placed himself in such a manner, that it would necessarily be stretched, if his arm should be convulsed again. He accordingly discharged the phial, and this wire was broken, like the former *.

MR. GEORGE GRAHAM shewed how several circuits for the discharge of the Leyden phial might be made at the same time, and the fire be made to pass through them all. He made a number of persons take hold of a plate of metal, communicating with the outside of the phial; and all together, likewise, laid hold of a brass rod with which the discharge was made; when they were all shocked at the same time, and in the same degree †.

LASTLY, Mr. Canton found, that if a charged phial was placed upon electrics, the wire and the coating would give a spark or two alternately; and that, by continuing this operation, the phial would be discharged ‡. This discovery, which is the first that I find recorded of this excellent philosopher, to whom the science of electricity owes so much, has a near affinity to the great discovery of

* Wilson's Essay, p. 84. † Ibid. p. 128.
‡ Ibid. p. 64.

Dr.

Dr. Franklin; but he did not then obferve, that thofe alternate fparks proceeded from the two contrary electricities. This hiftory will furnifh many more inftances of perfons being on the eve of great difcoveries, without actually making them. Both Mr. Gralath and Mr. Richman obferved, in feveral cafes, a ftronger fpark between two bodies, when both of them were electrified, than when only one of them was in that ftate; but neither of them fufpected that the electricities were of a different kind *.

We have feen what obfervations the Englifh philofophers had made upon the Leyden experiment before the time of Dr. Franklin; let us now take a view of what was done by electricians in other parts of the world, within the fame period.

As Mr. Mufchenbroeck's letter to Mr. Reaumur, concerning the experiment of the phial, came at a time when many learned men were employed about electricity, the Abbé Nollet, and Mr. De Monnier, gentlemen of the academy, zealous to fearch into fo an extraordinary a phenomenon, diverting themfelves of the fear with which the profeffor's letter had juftly infpired them, made the experiment upon themfelves, and, in like manner, faid they found the commotion very terrible. The report of it inftantly fpread through the court and the city, from whence all ranks of men crouded to fee this new

* Wilcke's Preface to the German Verfion of Franklin's Letters.

kind

kind of thunder, and to experience the effect of it *.

THE Abbé Nollet was the first who made experiments upon the phial in France, and the result of many of them was the same with what Dr. Watson had discovered, for which reason I shall not recite them here. They may all be seen at one view in his *Leçons de physique*, p. 481. The circumstances which the English philosophers had not attended to, are the following.

THE Abbé received a shock from a bottle out of which the air had been exhausted, and into which the end of his conductor had been inserted. As he was amusing himself with observing the beautiful irradiations of the electric light in the vessel, it immediately occurred to him, that, being so strongly electrified, it could not fail to give a shock similar to that of the Leyden phial, and without any farther reflection, laying one hand on the vessel, and bringing the other to the conductor, his conjecture was verified, but in a manner that gave him more pain than he could have wished. The blow he received was greater, he says, than he ever felt from the Leyden experiment in any other form †.

IN the same place he observes, that he never considered the water in the phial as of any use, but to convey the electric matter into the inside of the glass; and that he ascribed the force of the glass in giving a shock, to

* Nollet's Leçons de Physique, p. 452. Ac. Par. 1746. M. p. 5. † Recherches, p. 426.

that

that property of it, whereby it retained it more ſtrongly than conductors do, and was not ſo eaſily diveſted of it as they are. The Abbé alſo gave the ſhock with porcelain, and obſerved, that ſome perſons were much more ſenſible to it than others in whatever part of the circuit they were placed *.

MR. MONNIER is ſaid, by Mr. Buffon, to have been the firſt who diſcovered that the Leyden phial would retain its electricity a conſiderable time after it was charged, and to have found it do ſo for thirty-ſix hours, in time of froſt. He frequently electrified his phial at home, and brought it in his hand, through many ſtreets, from the college of Harcourt to his apartments in the King's garden, without any conſiderable diminution of its efficacy †.

In France as well as in Germany experiments were made to try how many perſons might feel the ſhock of the ſame phial. The Abbé Nollet, whoſe name is famous in electricity, gave it to one hundred and eighty of the guards, in the King's preſence; and at the grand convent of the Carthuſians in Paris, the whole community formed a line of nine hundred toiſes, by means of iron wires between every two perſons (which far exceeded the line of one hundred and eighty of the guards) and the whole company upon the diſcharge of the phial, gave a ſudden ſpring, at

* Ac. Par. 1746, M. p. 11, 26.
† Phil. Tranſ. abridged, Vol. x. p. 323.

the

the ſame inſtant of time, and all felt the ſhock equally *.

Mr. Nollet alſo tried the effect of the electric ſhock upon two birds, one of which was a ſparrow, and the other a chaffinch, which, as far as I can find, were the firſt brute animals of any kind that ever received it. The conſequence was, that upon the firſt ſhock, they were both inſtantaneouſly ſtruck motionleſs, and, as it were, lifeleſs, though for a time only; for they recovered ſome few minutes after. Upon the ſecond ſhock, the ſparrow was ſtruck dead, and, upon examination, was found livid without, as if it had been killed with a flaſh of lightning; moſt of the blood veſſels in the body being burſt by the ſhock. The chaffinch revived as before †. Fiſhes were alſo killed with the electric ſhock, by the Abbé, and others.

The circumſtance of the blood veſſels of the ſparrow being burſt is pretty ſingular. I have ſeen no ſuch effect, when ſmaller animals have been killed by a ſhock fifty times as great as, it is probable, the Abbé uſed upon this occaſion.

The Abbé Nollet, as well as Mr. Jallabert, mentions the burſting of glaſs veſſels by the electric exploſion. They were pierced, he ſays, with round holes, three or four lines in diameter ‡.

It ſeems that the French philoſophers, as well as the Engliſh, had obſerved, that, if the

* Phil. Tranſ. abridged, Vol. x. p. 335. † Ibid p. 336, Ac. Par. 1746. M. p. 32. ‡ Nollet's Lettres, Vol. i. p. 42.

phial

phial ſtood upon glaſs, it could not be charged, except a perſon's hand, or ſome other non-electric ſubſtance were brought near to it. Upon this they imagined the fire ſtreamed out of the hand, and paſſed through the ſubſtance of the phial into the water *. This fact ſurpriſed them very much, as it well might. Mr. Monnier obſerved, that a light body would be attracted by a charged phial, as it ſtood upon the table, and produced a ſpark if any perſon touched the wire; but that the light body muſt be ſuſpended by a non-electric ſubſtance †. He likewiſe found, that when the charged phial ſtood upon glaſs, it might be handled with all ſafety ‡. Theſe experiments ſeem not to have been made with proper circumſpection: for by an attention to theſe very circumſtances, Dr. Franklin was afterwards led to the great diſcovery of the different quality of the electricity, on different ſides of the glaſs.

* Phil. Tranſ. abridged, Vol. x. p. 334.
† Ac. Par. 1746, M. p. 684.
‡ Phil. Tranſ. abridged, Vol. x. p. [illegible]

SECTION

SECTION II.

The Methods used by the French and English philosophers, to measure the distance to which the electric shock can be carried, and the velocity with which it passes.

WE are now come to an ampler field of electrical experiments, in which we ſhall be ſpectators, not of what might be exhibited in a private room, and by a few operators, but where we ſhall find an amazing apparatus neceſſary, and a great number of aſſiſtants in the management of it; as well as the greateſt judgment, and the moſt unwearied patience in the conduct of it.

The French philoſophers were the firſt to appear in this field, but they excited the Engliſh to go far beyond them in theſe great undertakings. It has been ſaid already, that a circuit was made of nine hundred toiſes, conſiſting of men holding iron wires betwixt each two, through which the electric ſhock was ſenſibly felt. At another time, they made the ſhock paſs through a wire two thouſand toiſes in length, that is near a Paris league, or about two Engliſh miles and a half; though part of the wires dragged upon wet graſs, went over charmil hedges, or paliſades, and over ground newly ploughed up. Into another chain they took the water of the baſon

bason in the Thuilleries, the surface of which was about an acre, and the phial was discharged through it *. Mr. Monnier, who made this experiment, mentioning the quantity of surface in the bason of water, as if it was of consequence to the experiment, and saying it was *electrified*, (tho' all he meant by this was, that it received and transmitted the electric charge †.) Mr. Gralath made several experiments, which prove, that bodies which form the circuit of the shock are not properly electrified ‡.

Mr. Monnier the younger, also endeavoured to determine the velocity of the electric matter; and for this purpose, made the shock pass through an iron wire of nine hundred and fifty toises in length, but he could not observe, that it spent a quarter of a second in passing it. He also found, that when a wire of one thousand three hundred and nineteen feet, with its extremities brought near together, was electrified; the electricity ceased at one end, the moment it was taken off at the other. This fact refuted the opinion of those who maintained, that it was the force of the electrical *shock*, which threw the electric matter with so great velocity §.

These attempts of the French gave occasion to the greater, the more accurate, and the more numerous experiments of the English.

* Phil. Transf. abridged, Vol. x. p. 336.
† Ac. Par. 1746. M. p. 678.
‡ Dantzick Memoirs, Vol. iii. p. 552.
§ Ac. Par. 1746, M. p. 686.

The names of the English gentlemen, animated with a truly philosophical spirit, and who were indefatigable in this business, deserve to be transmitted to posterity in every work of this nature.

THE principal agent in this great scene was Dr. Watson. He planned and directed all the operations, and never failed to be present at every experiment. His chief assistants were Martin Folkes, Esq. president of the Royal Society, Lord Charles Cavendish, Dr. Bevis, Mr. Graham, Dr. Birch, Mr. Peter Daval, Mr. Trembley, Mr. Ellicott, Mr. Robins, and Mr. Short. Many other persons, and some of distinction, gave their attendance occasionally.

DR. WATSON, who wrote the history of their proceedings, in order to lay them before the Royal Society, begins with observing (what was verified in all their experiments) that the electric shock is not, strictly speaking, conducted in the shortest manner possible, unless the bodies through which it passes conduct equally well; for that, if they conduct unequally, the circuit is always formed through the best conductors, though the length of it be ever so great.

THE first attempt these gentlemen made, was to convey the electric shock across the river Thames, making use of the water of the river for one part of the chain of communication This they accomplished on the 14th and 18th of July 1747, by fastening a wire all along Westminster bridge, at a considerable

height above the water. One end of this wire communicated with the coating of a charged phial, the other being held by an obſerver, who, in his other hand, held an iron rod, which he dipped into the river. On the oppoſite ſide of the river, ſtood a gentleman, who, likewiſe, dipped an iron rod in the river, with one hand; and in the other held a wire, the extremity of which might be brought into contact with the wire of the phial.

Upon making the diſcharge, the ſhock was felt by the obſervers on both ſides the river, but more ſenſibly by thoſe who were ſtationed on the ſame ſide with the machine; part of the electric fire having gone from the wire down the moiſt ſtones of the bridge, thereby making ſeveral ſhorter circuits to the phial; but ſtill all paſſing through the gentlemen who were ſtationed on the ſame ſide with the machine. This was, in a manner, demonſtrated by ſome perſons feeling a ſenſible ſhock in their arms and feet, who only happened to touch the wire, at the time of one of the diſcharges, when they were ſtanding upon the wet ſteps which led to the river. In one of the diſcharges made upon this occaſion, ſpirits were kindled by the fire which had gone through the river *.

Upon this, and the ſubſequent occaſions, the gentlemen made uſe of wires, in pre-

* Phil. Tranſ. abridged, Vol. x. p. 394.

ference to chains, for this, among other reasons, that the electricity which was conducted by chains was not so strong, as that which was conducted by wires. This, as they well observed, was occasioned by the junctures of the links not being sufficiently close, as appeared by the snapping and flashing at every juncture, where there was the least separation. These lesser snappings, being numerous in the whole length of a chain, very sensibly lessened the great discharge at the gun-barrel.

THEIR next attempt was to force the electrical shock to make a circuit of two miles, at the New River at Stoke Newington. This they performed on the 24th of July. 1747, at two places; at one of which the distance by land was eight hundred feet, and by water two thousand: in the other, the distance by land was two thousand eight hundred feet, and by water eight thousand. The disposition of the apparatus was similar to what they before used at Westminster bridge, and the effect answered their utmost expectations. But, as in both cases, the observers at both extremities of the chain, which terminated in the water, felt the shock, as well when they stood with their rods fixed into the earth twenty feet from the water, as when they were put into the river; it occasioned a doubt, whether the electric circuit was formed through the windings of the river, or a much shorter way, by the ground of the meadow: for the experiment

ment plainly ſhewed, that the meadow-ground, with the graſs on it, conducted the electricity very well.

By ſubſequent experiments, they were fully convinced, that the electricity had not, in this caſe, been conveyed by the water of the river, which was two miles in length, but by land, where the diſtance was only one mile; in which ſpace, however, the electric matter muſt neceſſarily have paſſed over the New River twice, have gone through ſeveral gravels pits, and a large ſtubble field *.

July 28th, they repeated the experiment, at the ſame place, with the following variation of circumſtances. The iron wire was, in its whole length, ſupported by dry ſticks, and the obſervers ſtood upon original electrics; the effect of which was, that they felt the ſhock much more ſenſibly than when the conducting wire had lain upon the ground, and when the obſervers had likewiſe ſtood upon the ground, as in the former experiment.

Afterwards, every thing elſe remaining as before, the obſervers were directed, inſtead of dipping their rods into the water, to put them into the ground, each one hundred and fifty feet from the water. They were both ſmartly ſtruck, though they were diſtant from each other above five hundred feet †.

* Phil. Tranſ. abridged, Vol. x. p. 360.
† Ibid. p. 357.

The same gentlemen, pleased with the success of their former experiments undertook another, the object of which was, to determine, whether the electric virtue could be conveyed through dry ground; and, at the same time, to carry it through water to a greater distance than they had done before. For this purpose, they pitched upon Highbury-barn beyond Islington, where they carried it into execution on the 5th of August 1747. They chose a station for their machine, almost equally distant from two other stations for observers upon the New River; which were somewhat more than a mile asunder by land, and two miles by water. They had found the streets of London, when dry, to conduct very strongly, for about forty yards; and the dry road at Newington about the same distance. The event of this trial answered their expectations. The electric fire made the circuit of the water, when both the wires and the observers were supported upon original electrics, and the rods dipped into the river. They also both felt the shock, when one of the observers was placed in a dry gravelly pit, about three hundred yards nearer the machine than the former station, and one hundred yards distant from the river: from which the gentlemen were satisfied, that the dry gravelly ground had conducted the electricity as strongly as water.

From the shocks which the observers received in their bodies, when the electric power was conducted upon dry sticks, they were

were of opinion, that, from the difference of diſtance ſimply conſidered, the force of the ſhock, as far as they had yet experienced, was very little, if at all impaired. When the obſervers ſtood upon electrics, and touched the water, or the ground, with the iron rods, the ſhock was always felt in their arms or wriſts; when they ſtood upon the ground with their iron rods, they felt the ſhock in their elbows, wriſts, and ancles; and when they ſtood upon the ground without rods, the ſhock was always felt in the elbow and wriſt of that hand which held the conducting wire, and in both ancles *.

The laſt attempt of this kind which theſe gentlemen made, and which required all their ſagacity and addreſs in the conduct of it, was to try whether the electric ſhock was perceptible at twice the diſtance to which they had before carried it, in ground perfectly dry, and where no water was near; and alſo to diſtinguiſh, if poſſible, the reſpective velocity of electricity and ſound.

For this purpoſe, they fixed upon Shooter's-hill, and made their firſt experiments on the 14th of Auguſt 1747, a time, when, as it happened, but one ſhower of rain had fallen during five preceding weeks. The wire communicating with the iron rod, which made the diſcharge, was ſix thouſand ſeven hundred and thirty-two feet in length, and was ſupported all the way upon baked ſticks;

* Philoſophical Tranſactions abridged, Vol. x. p. 360.

as was alſo the wire which communicated with the coating of the phial, which was three thouſand eight hundred and ſixty-eight feet long, and the obſervers were diſtant from each other two miles. The reſult of the exploſion demonſtrated, to the ſatisfaction of the gentlemen preſent, that the circuit performed by the electric matter was four miles, viz. two miles of wire, and two of dry ground, the ſpace between the extremities of the wires; a diſtance which, without trial, as they juſtly obſerved, was too great to be credited. A gun was diſcharged at the inſtant of the exploſion, and the obſervers had ſtop watches in their hands, to note the moment when they felt the ſhock: but, as far as they could diſtinguiſh, the time in which the electric matter performed that vaſt circuit might have been inſtantaneous *.

IN all the exploſions where the circuit was made of conſiderable length, it was obſerved, that though the phial was very well charged, yet that the ſnap at the gun barrel, made by the exploſion, was not near ſo loud as when the circuit was formed in a room; ſo that a by-ſtander, ſays Dr. Watſon, though verſed in thoſe operations, would not imagine, from ſeeing the flaſh, and hearing the report, that the ſtroke, at the extremity of the conducting wire, could have been conſiderable; the contrary whereof, when the wires were properly managed, he ſays, always happened.

* Phil. Tranſ. abridged, Vol. x. p. 363.

STILL

STILL the gentlemen, unwearied in these pursuits, were desirous, if possible, to ascertain the absolute velocity of electricity at a certain distance; because though, in the last experiment, the time of it's progress was certainly very small, if any, they were desirous of knowing, small as that time might be, whether it was measureable, and Dr. Watson had contrived an excellent method for that purpose.

ACCORDINGLY, on the 5th of August 1748, the gentlemen met once more, and the last time, at Shooter's-hill; when it was agreed to make an electric circuit of two miles, by several turnings of the wire, in the same field. The middle of this circuit, they contrived to be in the same room with the machine, where an observer took in each hand one of the extremities of the wires, each of which was a mile in length. In this excellent disposition of the apparatus, in which the time between the explosion and the shock might have been observed to the greatest exactness, the phial was discharged several times; but the observer always felt himself shocked at the very instant of making the explosion. Upon this the gentlemen were fully satisfied, that through the whole length of this wire, which was 12276 feet, the velocity of the electric matter was instantaneous *.

THESE experiments excited the admiration of all foreign electricians. Professor Muschen-

* Phil. Trans. abridged, Vol. x. p. 368.

broeck,

broeck, who was greatly satisfied with the extent and success of them, said, in a letter to Dr. Watson, upon the occasion, *Magnificentissimis tuis experimentis superasti conatus omnium.*

It is said by some, that the last of these experiments go upon a wrong supposition, and therefore can be of no use; it being supposed that the very same particles of the electric fluid, which were thrown on one side of the charged glass, actually made the whole circuit of the intervening conductors, and arrived at the opposite side: whereas Dr. Franklin's theory only requires that the deficiency on one side of the glass be supplied from the neighbouring conductors; which may, in return, receive as much as they parted with, from the side of the glass that was overcharged. So that, to be a little more particular, the redundancy of electric matter on the charged side of a pane of glass, only passes into the bodies which form that part of the circuit which is contiguous to it, driving forward that part of the fluid which was natural to them; till, at length, the fluid which resided in those conductors which formed the last part of the circuit, passes into the exhausted side of the glass.

But should this be the case (though in great discharges it supposes the natural quantity of electricity in bodies to be very considerable) and should Dr. Watson, and other philosophers at that time, have conceived otherwise; it does not follow, that the experiments could possibly

poſſibly determine *nothing*: for there ſtill remains ſomething to be meaſured, viz. the time required for the ſucceſſive diſlodging the electric fluid in the whole length of the circuit.

WERE the whole maſs of the electric matter contained in all the intervening conductors abſolutely ſolid, no motion could be made at one extremity, without producing an inſtantaneous motion at the other; juſt as if one end of a rod be ſtruck, the motion is inſtantly communicated to the other end. But this cannot be the caſe in an elaſtic medium, the parts of which yield to one another. In this caſe, the motion is communicated in a real ſucceſſion, like a vibration, running the whole length of the circuit; which muſt therefore take up time, and be meaſurable. The motion of ſound may be meaſured, though no particle of the vibrating air be finally diſplaced. Theſe great experiments of Dr. Watſon, therefore, had a real object, only it appeared to be too ſmall to be aſcertained by them.

SECTION III.

MISCELLANEOUS DISCOVERIES OF DR. WATSON, AND OTHERS, BEFORE THE TIME OF DR. FRANKLIN.

THE firſt of theſe diſcoveries in order of time, and in importance ſecond to none (except that of the ſhock itſelf, and Dr. Franklin's diſcovery of the different electricity of the oppoſite ſides of the charged glaſs) was that of Dr. Watſon, proving, that the glaſs tubes and globes did not contain the electric power in themſelves, but only ſerved as *firſt movers*, and *determiners*, as he calls it, of that power.

HE was firſt led to this diſcovery by obſerving, that, upon rubbing the glaſs tube, while he was ſtanding upon cakes of wax (in order, as he expected, to prevent any of the electric power from diſcharging itſelf through his body upon the floor) the power was, contrary to his expectation, ſo much leſſened, that no ſnapping could be obſerved upon another perſon's touching any part of his body; but that if a perſon not electrified held his hand near the tube, while it was rubbed, the ſnapping was very ſenſible *.

THE event was the ſame when the globe was whirled in ſimilar circumſtances. For if

* Phil. Tranſ. abridged, Vol. x. p. 303.

the

the man who turned the wheel, and who, together with the machine was suspended upon silk, touched the floor with one foot, the electric fire appeared upon the conductor; but if he kept himself free from any communication with the floor, no fire was produced.

DR. WATSON by this, and the following experiments in conjunction, discovered, what he calls, the complete circulation of the electric matter. He observed, that only a spark or two would issue from his hand to the insulated machine, unless he, at the same time, formed a communication between the conductor and the floor; but that then there was a constant and copious flux of the electric matter to the machine.

OBSERVING, that while his hand was in contact with the conductor, the man who turned this insulated machine gave sparks, which would fire inflammable substances, and perform other electrical experiments which were usually performed at the conductor; he naturally imagined, that the fire issued from the man, for the very same reason that all electricians had before imagined that it came from the conductor; and seeing that the man gave no fire unless there was a communication between the floor and the conductor, he concluded that, in this case, the fire was supplied by that communication, so that the course of the electricity was inverted, as he expresses it *.

* Phil. Transf. abridged, Vol. x. p 305.

It was not then suspected, that the eye could not distinguish in what direction an electric spark proceeds. Electricians naturally imagined that all electric powers, and consequently the electric fluid, which they supposed to be the cause of these powers, existed in the excited electric, whatever it was; and that whatever powers were exerted by electrified bodies, proceeded from a real communication of electric matter to them. Accordingly, when Dr. Watson found that, by cutting off the communication of the electric with the floor, all electrical operations were stopped, he concluded, that the electric fluid was collected from the floor to the rubber, and thence conveyed to the globe. For the same reason, seeing the rubber, or the man who had a communication with it, give no sparks but when the conductor was connected with the floor, he would as naturally conclude that the globe was supplied from the conductor, as he had before concluded that it was supplied from the rubber.

Comparing both these experiments together, Dr. Watson was led to infer, that, in all electrical operations, there was both an *afflux* of electric matter to the globe, and the conductor, and likewise an *efflux* of the same electric matter from them *.

Finding that a piece of leaf silver was suspended between a plate electrified by the conductor, and another communicating with the

* Phil. Transf. abridged, Vol. x, p. 311.

floor,

floor, he reasons from it in the following manner. "No body can be suspended in "equilibrio but by the joint action of two "different directions of power: so here, the "blast of electric ether from the excited "plate blows the silver towards the plate un-"excited, and this last, in its turn, by the "blast of electric ether from the floor setting "through it, drives the silver towards the "plate electrified. We find from hence, "likewise, that the draught of electric ether "from the floor is always in proportion to "the quantity thrown by the globe over the "gun barrel, or the equilibrium by which "the silver is suspended could not be main-"tained *."

Dr. Watson observes, that the Abbé Nollet, two years before he made this communication, had given it as his opinion (though without any experiment which proved it) that the electric matter did not only proceed from the electrified bodies, but from all others about them, to a certain distance †.

Some time after this, Dr. Watson observes, in a paper read at the Royal Society, January 21st, 1748, that Dr. Bevis had carried his experiment, to prove that rubbing the tube or the globe, only conveyed, and did not produce the electric matter, farther than he had done. For he had observed, above a year before, that placing one man upon electrics, to rub the tube or globe, and another

* Phil. Transf. abridged, Vol. x. p. 310.
† Ibid. p. 315.

also

alſo upon electrics to touch them, as the conductor; both the man who rubbed, and the man who touched the excited glaſs would give a ſpark; and farther, that if they touched one another, the ſnapping was much greater than if either of them touched a perſon ſtanding upon the floor. Upon this the Doctor ſeems to have corrected his former opinion of the afflux and efflux of electric matter: for he accounts for this fact by ſuppoſing, that as much electricity as was taken from the perſon rubbing was given to him who touched the conductor, being conveyed by the globe. By this means the electricity of the former of theſe perſons, he obſerves, was more rare than it naturally was, and that of the latter more denſe; ſo that the denſity of electricity between theſe two perſons differed more than that between either of them, and another perſon ſtanding upon the floor. In this manner did Dr. Watſon diſcover, what Dr. Franklin obſerved, about the ſame time, in America, and called the *plus* and *minus* in electricity *.

Dr. Watson obſerved that the flame at the end of an electrified wire was ſenſible to the hand, as a cool blaſt of wind, and that when light ſubſtances were attracted and repelled between an electrified plate and one communicating with the floor, the ſucceſſion of theſe alternate attractions and repulſions was extremely quick, ſo that ſometimes the

* Phil. Tranſ. abridged, Vol. x. p. 369.

eye

eye could hardly keep pace with it; and that when a glaſs globe, of about an inch in diameter, very light and finely blown, was put upon a plate of metal, and another plate hung on the conductor over it, the ſtrokes from the alternate attractions and repulſions were almoſt too quick for the ear. From this laſt experiment he likewiſe deduced an argument to prove the extreme velocity with which theſe glaſs globes were attracted and repelled. He ſays, that if they were let fall from the height of ſix feet or more upon a wooden floor, or even a plate of metal, they were rarely broken; but that by the attraction and repulſion of them between theſe plates, though at the diſtance of no more than one ſixth of an inch, they were frequently beaten to pieces *.

THE Doctor alſo proved, that the electric matter paſſed through the ſubſtances of the metal of communication, and not over the ſurface of it, by covering a wire with a mixture of wax and roſin, and diſcharging a phial through it.

I MUST here obſerve, that Mr. Monnier the younger diſcovered, that electricity is not communicated to homogeneous bodies in proportion to their maſſes or quantity of matter, but rather in proportion to their ſurfaces; and yet that all equal ſurfaces do not receive equal quantities of electricity, but that thoſe receive the moſt which are moſt extended in length; that a

* Phil. Tranſ. abridged, Vol. x. p. 309.

ſquare ſheet of lead, for inſtance, received a much leſs quantity of electricity than a ſmall ſtrip of the ſame metal with a ſurface equal to that of a ſquare ſheet *.

Mr. Wilson, whoſe curious obſervations on the Leyden phial have been mentioned in a former ſection, claims no ſmall ſhare of honour in this. As early as the latter end of the year 1746, he made the ſame diſcovery that Dr. Watſon had done, viz. that the electric fluid did not come from the globe, but from the earth itſelf, and from all other non-electric bodies about the apparatus. He ſuggeſted a method of proving this in a letter to Mr. Ellicott from Cheſter; and mentions his having completed the experiment himſelf ſoon after, in a letter to Mr. Smeaton, from Dublin.

Having conceived that the difference between electric and non-electric bodies was owing to the different reſiſtance which a *ſubtle medium*, as he calls it, on the ſurfaces of all bodies gave to the paſſage of the electric fluid; and conceiving that heat would rarify this medium, and thereby convert electrics into non-electrics, he made ſome experiments which confirmed him in that ſuppoſition. He found that one perſon might communicate electricity to another, notwithſtanding the intervention of a conſiderable quantity of red-hot glaſs. He alſo made other experiments of a ſimilar nature, as diſcharging phials by means of hot glaſs, hot amber,

* Phil. Tranſ. abridged, Vol. x. p. 338.

and

and various other heated electrics. These, however, as Mr. Canton afterwards observed, might be owing to the hot air upon the surfaces of those bodies, which he found to transmit electricity very well. But another experiment, which Mr. Wilson made upon melted rosin, does not seem liable to that objection. He poured the melted rosin into a phial, and found that he could give shocks with it; but he observed, that these shocks diminished as the rosin grew cold, and that when it was quite cold, they entirely ceased *.

MR. WILSON mentions a curious experiment (of which, however, he does not say that he was the inventor) which he made with paper vanes stuck in a cork, and suspended by a magnet. These, he says, if they were brought near the point of any body proceeding from the prime conductor, would turn round very swiftly, but would not turn at all in vacuo. This blast he thought was occasioned by the issuing of the electric matter out of the point, which caused a current in the air; but he did not try what would be the consequence of presenting the vanes to a point which received the electric fluid †.

LASTLY, Mr. Wilson observed, that if a needle were presented to a piece of down hanging to the conductor, it would cling close to it; but that, upon presenting any thing that was blunt, it would be repelled again; and says that Mr. Canton made

* Wilson's Essay, p. 143. † Ibid. p. 141.

ſeveral curious experiments of the ſame kind *.

MR. SMEATON, within this period, obſerved, that if a man who was inſulated preſſed againſt the globe with the flat part of his hand, while another perſon, ſtanding on the floor, did the ſame, in order to excite it, the perſon who was inſulated would hardly be electrified at all; but that, if he only laid his fingers lightly on the globe, he would be electrified very ſtrongly †. The ſame ingenious perſon alſo obſerved, that upon heating the middle of a large bar of iron to a glowing heat, and electrifying it, the electric power of the part that was heated was as ſtrong as that of the cold part ‡.

FOR ſeveral curious diſcoveries relating to electricity, made within this period, we are indebted to Dr. Miles. In a paper read at the Royal Society, January 25th, 1746, he ſays, that having excited a ſtick of black ſealing-wax with white and brown paper, or clean dried flannel, he was able to kindle common lamp-ſpirits with it. Comparing the ſtick of wax with the glaſs tube, he obſerved a remarkable difference between the appearance of fire from both, though he did not underſtand the reaſon of it. He ſays he found the luminous effluvia to proceed in a much greater quantity from the top of his finger to the ſtick of wax, than they did to the glaſs. He ſeveral times obſerved a ſmall

* Wilſon's Eſſay, p. 141. † Ibid. p. 153.
‡ Ibid. p. 129.

globular

globular ſpot of fire to appear firſt on his finger, from which iſſued regular ſtreams towards the wax, in the form of a comet's tail. This is now well known to be the conſtant appearance of the electric fire between an unelectrified body and an electric excited negatively *.

DR MILES found a ſtick of ſulphur to perform very well; but not at all, when he had put an iron rammer in the center of it, to ſtrengthen it. It is remarkable, that after ſetting this ſtick upright in a cupboard, it loſt all its electric virtue, and could never afterwards be excited in the leaſt degree. This effect the Doctor attributed to its being put up without any cover.

DR. MILES alſo mentions his having got a a tube of green glaſs, which he could never excite but with great difficulty, and then but to a ſmall degree †.

THE ſame ingenious gentleman, ſome time after, made an experiment upon pieces of leaf braſs in a bottle hermetically ſealed. To theſe he found he could give motion by the approach of the excited tube, in the ſame manner as if they had been in the open air; but one appearance ſtruck him, of which he by no means gives a ſatisfactory account. He obſerved that when he removed the tube from the exhauſted glaſs ſlowly, no commotion was ſeen in the leaf braſs, but a very briſk one

* Wilſon's Eſſay. p. 317.
† Phil. Tranſ. abridged, Vol. x. p. 320.

upon removing it ſuddenly. Indeed this fact could not have been underſtood but by comparing it with other facts depending upon the ſame principle, and which were not diſcovered till ſome years after *.

From England, to which, as an Engliſhman, I would give the preference only in matters of abſolute indifference, I paſs over to France, where, next to thoſe made in England, the moſt important diſcoveries, and greateſt number of them were made in the period of which I am treating. And, without all diſpute, the greateſt name in France, in this or any other period, except that of Mr. Du Fay, his friend and aſſociate, is that of the Abbé Nollet.

The favourite obſervation of Mr. Nollet, on which he built his darling theory of affluences and effluences was, that bodies not inſulated, plunged in electric atmoſpheres, ſhewed ſigns of electricity. He obſerved a ſenſible blaſt from the hand of a perſon not electrified, in the above mentioned circumſtances, alſo the attraction and repulſion of light bodies by them, the appearance of flame, the diminution of their weight by increaſed evaporation and perſpiration, and almoſt every other appearanc and effect of electricity. Moreover obſerving that his globe contracted a foulneſs while it was whirling, even when rubbed with a clean hand, he had the curioſity to collect a quantity of the mat-

* Phil. Tranſ. abridged, Vol. x. p. 326.

ter

ter which formed that foulness; and finding that, when it was put into the fire, it had the smell of burnt hair, he concluded that it was an animal substance; and that it had been carried by the affluent electricity from his own body to the globe *.

THE only mistake of this ingenious philosopher in these experiments, and which was the source of many others, which, in the end, greatly bewildered and perplexed him, was, that the electricity of the body, which was plunged in the atmosphere of an electrified body, was of the same nature with that of the electrified body. Had he but preserved the distinction, which Mr. Du Fay had discovered, between the two electricities, and imagined that the body electrified, and that which was plunged in its atmosphere were possessed of these two different and opposite electricities, he might have been led to the great discoveries made by Mr. Canton, Dr. Franklin, and Mr. Wilcke; which, we shall find, arose from that single observation; and he would have avoided a great deal of debate and contention, which has not ended to his advantage.

THIS partial discovery of Mr. Nollet is by no means the only one of his, that the history of electricity presents in this period. He made several experiments on pointed bodies, and observed, that those which had the smallest points soonest threw out brushes of

* Nollet's Recherches, p. 142.

electric light, but did not show other signs of electricity so strong as bodies that were not pointed *.

He took a great deal of pains in making experiments, in order to determine the degree in which different substances conducted the electric fluid; and found that the smoke of gum lac, turpentine, karabé, and sulphur did not carry away the electricity of an excited tube so soon as the smoke of linen, wood, and more especially the steam of water, and the effluvia of burning tallow, and of other fatty substances. In short, he found, that vapours which were not watery did very little, or no injury to electrical experiments, provided the tube was not exposed to them near the fire which caused them. A smoky room did not prevent his performing experiments, at least in any great degree; nor were odoriferous effluvia at all prejudicial to them †.

Several curious observations were made by the Abbé upon heat, and heated bodies. He found, that a piece of iron glowing hot, so as to throw off ignited particles, did not leave the smallest trace of electricity in an excited tube, to which it had been brought within five or six inches, and only held there two or three seconds; but it ceased to affect the tube at the same distance before it ceased to be red, and had no influence at all long before it was cold. The electricity of the tube, in this instance, was probably conveyed through

* Recherches, p. 146. † Ibid. p. 194, &c.

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the air heated by the iron; as it can hardly be supposed, that the iron emitted any effluvia capable of producing that effect *.

He found that the excited tube lost nothing of its electricity in the focus of a burning mirror. That the flame of a candle, or the near approach of it, would destroy electricity had been known before: he observed, that the flame was sensibly disturbed by the approach of the excited tube, and he mentions Mr. Du Tour, and the Abbé Needham's having found, that the interposition of the thinnest piece of glass, or of any other substance, between the candle and the tube prevented the dissipation of the electricity. From this fact it was inferred, that the dissipation was owing to some effluvia proceeding from the candle †.

CONTINUING his observations on what increased or impeded electrical experiments, he found, that a light body, placed on a non-electric stand, moved more briskly upon the approach of an electrified body, than when it was placed upon an electric stand ‡. Several electrical experiments, he observed, succeeded best when there was a number of spectators present, and when they drew near, and stood close together to see his experiments; provided they did not occasion so great a perspiration as made his glasses moist §. This observation we shall find accounted for hereafter by Mr. Wilcke.

* Recherches, p. 216. † Ibid. p. 219.
‡ Ibid. p. 122. § Ibid. p. 123.

THE

The Abbé moiſtened, with water or ſpirit of wine, a ſlender and pointed bar of iron, and thought that the blaſt from the point of it was more ſenſible than when it was not moiſtened; which he attributed to the electric fluid carrying away with it ſome of the particles of the water, and of the ſpirit of wine *.

Some few obſervations the Abbé made on the difference between excited and communicated electricity, and between the electricity of glaſs and that of ſulphur. He obſerved, that the electricity of an excited globe or tube, cauſed an odd ſenſation upon the face, as if a ſpider's web were drawn over it; whereas that effect was ſeldom produced by communicated electricity. Excited electricity, he alſo ſays, might be perceived by the ſmell, at more than a foot diſtance, when communicated electricity could not †.

He melted ſulphur in a glaſs globe, by turning it over a chafing diſh of burning coals; when he obſerved, that ſmall pieces of ſulphur, before they were melted, were attracted and repelled by the glaſs within, at the ſame time that the aſhes of the coals were attracted without ‡. Holding a piece of excited ſulphur in one hand, with a piece of down ſticking to it, and ready to fly off, the down, he ſays, would cling faſt to the ſulphur, upon preſenting to it an excited glaſs, tube, which he held in his other hand §.

* Recherches, p. 140. † Ibid. p. 136.
‡ Ibid. p. 184. § Ibid. p. 124.

I SHALL

I SHALL, in the laſt place, recite the Abbé Nollet's experiments made in vacuo. He found that glaſs, and other electrics, might be excited in vacuo, but not ſo ſtrongly as in the open air *. He obſerved that there was a remarkable difference between the appearance of the electric light in vacuo, and in the open air; being much more diffuſe, and unbroken in vacuo †. Inſerting the extremity of his conductor into an exhauſted glaſs veſſel, he obſerved the veſſel to be full of light, whenever he brought his hand to it; that the light was conſiderably increaſed when he ſpread his hand over it; and that when a ſpark was taken from the conductor, the whole veſſel ſeemed to be full of light. He alſo obſerved, that ſmall pieces of metal, incloſed in the veſſel, adhered cloſe to the glaſs; but detached themſelves from it, on the approach of the finger, or of any conductor on the outſide.

M. MONNIER attempted, in an ingenious method, to be certain whether the quantity of electricity communicated to a body was in proportion to its ſolid or ſuperficial contents. He firſt found that an anvil which weighed two hundred pounds, gave but an inconſiderable ſpark, while the ſpark from a ſpeaking-trumpet of tin, which weighed but ten pounds, but was eight or nine feet long, was almoſt equal to the ſhock of the Leyden phial. He then obſerved, that a ball of

* Recherches, p. 236. † Ibid. p. 243.

lead

lead four inches in diameter, gave a spark of the same force with another from a thin piece of lead of the same superficies, in the form of a hoop. And, lastly, he took a thin and long piece of lead, and observed, that when it was electrified in its whole length, it gave a very strong spark, but a very small one when it was rolled into a lump. But, because a square piece of lead did not give a spark equal to one from a piece of the same quantity of surface, but of greater length, he concluded that, though electrification is stronger in proportion to the surfaces of electrified bodies, yet that, of equal surfaces, that which is drawn out to the greatest length will have the advantage *.

THERE are a few other names of electricians in France, whose experiments and observations, made within this period, deserve to be mentioned. Of these is Mr. Boulanger. He took great pains to determine the degree in which different substances are capable of being excited. The experiments, he says, were made with the greatest care: and though the state of the science did not admit of this business being determined with greater accuracy, it may not be disagreeable to see the result of them; which he has comprised in the following table, beginning with those that are least excitable in every column.

* Ac. Par. 1746, M. p. 693.

FIRST COLUMN.

Ebony.
Guiacum.
Box wood.
Sandal wood.
Oak.
Elm.
Ash.
Linden tree.
Rose.
Willow.
Ozier.
Cork.
Dry wood of all kinds.
All dry plants.

SECOND COLUMN.

Shells of all kinds.
Whalebone.
Bones.
Ivory.
Horn.
Scales.
Parchment.
Hair.
Wool.
Feathers.
Cotton.
Silk.

THIRD COLUMN.

Alum.
Sugar Candy.
The Phosphorus of Berne.
Yellow and white wax.
Japan varnish.
Sandarac.
Mastich.
Amber.
Jet.
Pitch.
Gum copal.
Gum lac.
Colophonia.
Sulphur.
Sealing-wax.
All salts which have sufficient consistence.
All resins.

FOURTH COLUMN.

Loadstone.
Hand-stone.
Marble of all colours.
Slate.
Free-stone.
Granite.
Porphyry.
Jasper.
Varnished earth.
Cornelians.
Agates.
All opaque precious stones.
Porcelaine.

FIFTH

FIFTH COLUMN.

Hyacinth.
Opal.
Emerald.
Amethyst.
Topaz.
Ruby.
Sapphire.
Cat's eye.
Peridote.
Granite.
Rock crystal.
Venice and Muscovy talc.
Coloured diamonds, especially yellow.
White diamonds, especially the brilliant.
All transparent precious stones.
Glass, and all vitrifications without excepting those of metals.

THE inference which this author draws from this catalogue is, that the most brittle, and the most transparent substances, are always the most electric; and he has recourse to an awkward hypothesis to account for the marcasites not being excitable at all, notwithstanding they are both brittle and transparent. He says it is owing to condensed air contained in those substances, which is known to prevent excitation *.

THE same author says, that mineral waters are much more sensibly affected with electricity than common water; that black ribbons are much sooner attracted than those of other colours; and, next to them, the brown, and deep red †.

* Boulanger, p. 74.

† Ibid. p. 124.

MR.

MR. LE CAT, a phyſician at Rouen, who has diſtinguiſhed himſelf by ſeveral performances in the learned world, ſuſpended ſeveral pieces of leaf gold at his conductor, and obſerved that they hung at different diſtances, according to their ſizes, the ſmaller pieces placing themſelves nearer the conductor, and the larger receding farther from it. This he compares to the diſtances at which the planets make their revolutions round the ſun, and he ſuppoſed the cauſe to be the ſame in both. The ſame author very particularly compares the electric ſhock, which had juſt been diſcovered, to thunder *.

GERMANY affords but few articles for the electrical hiſtory of this period; one of them, however, is curious, and well deſerves to be tranſmitted to poſterity. Mr. Gordon of Erford excited the electricity of a cat ſo ſtrongly, that, when it was communicated by iron chains, it fired ſpirit of wine †.

IT has been mentioned before, that ſeveral gentlemen in Germany, as well as in England, had found, that if the man who rubbed the globe ſtood upon electrics, ſparks were perceived upon touching him; but Mr. Klingenſtierna, a Swede, and Mr. Stroema, were the firſt who properly electrified by the rubber; and their experiments were publiſhed in the Acts of the Royal Academy of Sciences at Stockholm for the year 1747 ‡.

* Hiſtoire, p. 84—85.

† Nollet's Recherches, p. 98.

‡ Wilcke, p. 112.

MR.

Mr. Jallabert, professor of philosophy at Geneva, found that a coating of pitch did not prevent the conductor from being electrified, which proved that the electric fluid enters the substance of metals. He also proved, that ice was a conductor of electricity, by making the Leyden experiment with a bottle in which water was frozen *.

The amazing and extensive effects of electricity now began to make philosophers look for it where it had not been suspected before. The first account that is given of woollen garments being observed to exhibit signs of electricity, when they were put off, after the flashes of light they gave were known to be owing to electricity, was sent to the Royal Society by Mr. Coke of the Isle of Wight, who says, that a lady of his acquaintance observed it; and that it was also at last found, that it was only new flannel, and after some time wearing, which gave that appearance, and that this property was lost when it was washed †.

The same appearance, he observes, upon another occasion, was most conspicuous in frosty weather; in which season he takes notice, that there is generally, not only a greater purity of the air, and absence of moisture, but that all hairy and horny substances (for hairs, as he says, are only small horns) are more elastic, and consequently susceptible of, and more capable of exciting strong vi-

* Histoire, p. 95, 96.
† Phil. Transf. abridged, Vol. x. p. 343.

brations.

brations. He says, that the flannel being rendered damp with sea water, and afterwards dry, would heighten the electric appearances *.

BUT though this was the first appearance of the kind that was observed, after it was known to arise from electricity, similar appearances had been several times noted before. Bartholin, who flourished in 1650, wrote a book *De luce animalium*, in which he supposes, that unctuous effluvia had a great share in those appearances. The same writer says, that Theodore Beza might be seen by a light proceeding from his eye-brows; and that sparks would flash from the body of Charles Gonzaga, Duke of Mantua, upon being gently rubbed. But he does not say whether he had any particular hairy, or scaly superficies to his skin †.

DR. SIMPSON, who published a philosophical discourse on fermentation, dedicated to the Royal Society in 1675, also takes notice of the light proceeding from animals on frication, or pectation as he calls it, and instances in the combing of a woman's head, the currying of a horse, and the stroking of a cat's back ‡.

MR. CLAYTON also, in a letter to Mr. Boyle, dated June 23d, 1684, at James-town in Virginia, gives him an account of a strange accident, as he calls it, which happened to one Mrs. Sewall, whose wearing apparel emit-

* Phil. Transf. abridged, Vol. x. p. 344. † Ibid. p. 344. ‡ Ibid. p. 337.

ted a flashing of sparks, which were seen by several persons. The like happened to Lady Baltimore her mother-in-law *.

I SHALL conclude this section with what I can find, in this period, about increasing the power of electricity, and measuring its effects.

MR. MONNIER the younger, whose name has been frequently mentioned in the course of this history, used glass spheroids instead of globes, and endeavoured to increase his electrical power by using several of these spheriods at a time; but he found, upon trial, that they did not answer his expectations; and was thence disposed to conclude, that there might be a *ne plus ultra* in the intensity of electricity, as well as in the heat communicated to boiling water †.

THE power of glass in electrifying being found to be so great, it is no wonder that philosophers should endeavour to find what kind of glass was capable of being excited to the greatest degree. Among other proposals we find a very memorable one communicated to the Royal Society, April 6th, 1749, by Mr. Boze. He says, that a glass ball which has often been employed in violent distillations, and other chemical operations sends forth electricity incomparably more strong, than any glass which had never been exposed to so violent a fire. This article is the more curious, as it shews us how much philosophers at this

* Phil. Transf. abridged, Vol. x. p. 278.
† Ibid. p. 330.

time

time piqued themselves upon discoveries in electricity. He asserts his being the first person who ever mentioned this notable circumstance, as he calls it, and desires Dr. Watson, to whom he communicated it, to let him have the honour of that improvement in the Philosophical Transactions *.

It was within this period that Dr. Watson contrived to improve the strength of electricity by moistening the rubber of his globe, though he was not aware of all the reasons for it. He observed that the man who stood on the floor, to excite the globe by his hand, did it more strongly than a cushion. This, he says, he could not conceive to be owing to any other difference, than to his hand being more moist, and consequently more readily conducting the electricity from the floor; wherefore he ordered his machine, and even his cushion, to be made damp; and then found that the electricity was as strong as when the globe was rubbed by the hand †.

A gentleman at Chartres in France, greatly increased the effects of electricity by means of moisture, for asserting which he is very much ridiculed by the author of *Histoire de l'Electricité*.

Mr. Wilson says, that if the cushion (which he made of leather) was gilt with silver, brass, or copper, it would do very well; and that the silk line on which the conductor

* Phil. Transf. abridged, Vol. x. p. 329.
† Ibid. p. 312.

hung ſhould be red or yellow *. The table, he ſays, ſhould ſtand on moiſt ground, or a wire paſs from the machine to the moiſt ground †.

Dr. Watson alſo found, that though no electricity could be produced by rubbing the globe with original electrics perfectly dry, yet that they anſwered very well when they had been made moiſt; the water imbibed by thoſe ſubſtances ſerving as a canal of communication to the electricity between the hand, or the cuſhion, and the globe; in the ſame manner as the air, replete with vapours in damp weather, prevents the accumulation of the electric matter in any conſiderable degree, by conducting it as faſt as it is excited to the neareſt non-electrics. He obſerved, on the contrary, that moſt vegetable ſubſtances, though made as dry as poſſible, furniſhed electricity, but ſmall in quantities. He excited electricity not only from linen, cotton, &c. but even from ſheet lead and a deal board ‡.

The Abbé Nollet ſays, that he found oil of turpentine upon a piece of woollen cloth excited glaſs very powerfully, but that the leaſt water mixed with it prevented the excitation §.

Mr. Boulanger ſays, that if two cylinders be made of the ſame kind of glaſs, and of the ſame faſhion, one of them tranſparent, and the other tinged with any colour, the tranſparent cylinder will be excited more eaſily

* Wilſon's Eſſay, p. 5, 6. † Ibid. p. 8.
‡ Ibid. 380. § Recherches, p. 168.

than

than the coloured one *. He acknowledges, however, that sometimes the moſt tranſparent, and the moſt brittle glaſs is capable of acquiring but little electricity †. In another place he ſays, that a cylinder of three or four lines in thickneſs will acquire a ſtronger, and a more laſting electricity than a cylinder of one line thick ‡. He alſo ſays, that a perſon's two hands, or one cuſhion, is better than more §.

About the ſame time that Dr. Watſon made his firſt experiments upon the Leyden phial, Mr. Canton diſcovered a method by which the quantity of electricity accumulated in the phial might be meaſured to a good degree of exactneſs. He took the charged phial in his hand, and made it give a ſpark to an inſulated conductor, which ſpark he took off with his other hand. This operation he repeated till the whole was diſcharged, and he eſtimated the height of the charge by the number of the ſparks. This is a pretty certain and exact method of knowing how high a phial *has been* charged; but what electricians chiefly want is a method of aſcertaining how high a phial *is* charged, or the exact force of the charge while it is contained in the glaſs.

Something of this kind was done by Mr. Ellicott, in the ſame year 1746. He propoſed to eſtimate the ſtrength of common

* Boulanger, p. 64. † Ibid. p. 164.
‡ Ibid. p. 135. § Ibid. p. 136.

electrification, by its power to raise a weight in one scale of a balance, while the other should be held over the electrified body, and pulled to it by its attractive power *. Mr. Gralath also constructed an electrometer upon the same principle †.

The Abbé Nollet applied the threads that Mr. Grey and Du Fay had used in electrical experiments, to shew the degree of electricity. He hung two of them together, and observed the angle of their divergence, by means of the rays of the sun, or the light of a candle, and their shadow upon a board placed behind them. Mr. Waitz also thought of the same kind of electrometer, with this improvement, that he loaded the ends of the threads with small weights ‡.

* Boulanger, p. 324.
† Dantzick Memoirs, Vol. i. p. 525.
‡ Histoire, p. 58.

SECTION

SECTION IV.

EXPERIMENTS ON ANIMAL, AND OTHER ORGANIZED BODIES IN THIS PERIOD; AND OTHER EXPERIMENTS CONNECTED WITH THEM, MADE CHIEFLY BY THE ABBE NOLLET.

HITHERTO the effect of electricity upon human bodies had not been attended to, farther than the mere ſhock of the Leyden phial. But we ſhall now ſee a curious ſet of experiments on this ſubject exhibited by the Abbé Nollet. The Engliſh philoſophers, who led the way in almoſt every other application of electricity, were among the laſt to try its effects upon animals, and other organized bodies. The only article that I can find upon this ſubject, before the diſcoveries of the Abbé Nollet, is one of Mr. Trembley's; who ſays that ſeveral perſons had obſerved, that while they were electrified, their pulſe beat a little faſter than before. He ſays, that he himſelf, after having been electrified a long time together, had felt an odd ſenſation all over his body, and that ſome perſons had felt very ſharp pains after being electrified *.

* Phil. Tranſ. abridged, Vol. x. p. 321.

The ingenious Abbé Nollet begins his experiments with the evaporation of fluids by electricity. They were made with the greatest attention, and the following observations were the result of them.

"1. Electricity augments the natural "evaporation of fluids; since, excepting mer-"cury, which is too heavy, and the oil of "olives, which is too viscous, all the others "which were tried suffered a diminution "which could not be ascribed to any other "cause than electricity.

"2. Electricity augments the evapo-"ration of those fluids the most, which are "most subject to evaporate of themselves. For "the volatile spirit of sal ammoniac suffered a "greater loss than spirit of wine, or turpen-"tine; these two more than common water; "and water more than vinegar, or the solu-"tion of nitre.

"3. Electricity has a greater effect "upon fluids when the vessels which contain "them are non-electrics; the effects always "seeming to be a little greater when the "vessels were of metal, than when they were "of glass.

"4. This increased evaporation was more "considerable when the vessel which contain-"ed the liquor was more open, but the ef-"fects did not increase in proportion to their "apertures. For when these liquors were "electrified in vessels, whose aperture was "four inches in diameter, though they pre-"sented to the air a surface sixteen times

"larger

" larger than when they were contained in " vessels whose aperture was one inch in diameter, they were, nevertheless, far from " suffering a diminution proportioned to that " difference.

" 5. ELECTRIFICATION does not make " any liquors evaporate through the pores, " either of metal, or of glass; since after experiments which were continued ten hours, " there was found no diminution of their " weight, when the vessels in which they were " contained were well stopped *."

AFTER having made experiments on fluids, the Abbé began another course on solids of various kinds, the result of which was, that they lost weight only in proportion to the moisture they contained, and the openness of their pores †.

THE Abbé also extended his experiments to other sensible qualties of bodies, as their smell, their taste, and chemical properties; but found no change in any of them, after a strong and continued electrification of a variety of substances. Electrification did not affect the power of the magnet, and neither retarded nor accelerated the heating or cooling of bodies ‡.

HE then proceeded to the electrification of capillary tubes, full of water; it having been observed by Mr. Boze, who communicated the observation to Mr. Nollet ||, that the water would issue in a constant stream when they

* Nollet's Recherches, p. 327. † Ibid. p. 335.
‡ Ibid. p. 341. || Ibid. p. 343.

were

were electrified; whereas it would only drop very ſlowly without that operation. Every perſon, at firſt ſight, would judge that the ſtream was accelerated, and that the electrified veſſel would ſoon be empty: but this accurate philoſopher was unwilling to rely on firſt appearances, and therefore reſolved to aſcertain the fact, by meaſuring the time, and the quantity of liquor running out. And, in order to know if the acceleration, ſuppoſing there were any, was uniform, during the whole time of the running out, he made uſe of veſſels of different capacities, terminating in pipes of different bores, from three lines in diameter, to the ſmalleſt capillaries.

As the Abbé did not find it ſo eaſy a matter to draw a ſafe concluſion in this caſe as might at firſt be imagined, he gives us in groſs the following reſult of above an hundred experiments *,

"1. The electrified ſtream, though it "divides, and carries the liquid farther, is "neither ſenſibly accelerated nor retarded, "when the pipe through which it iſſues is "not leſs than a line in diameter.

"2. Under this diameter, if the tube is "wide enough to let the liquid run in a con-"tinued ſtream, electricity accelerates it a "little; but leſs than a perſon would ima-"gine, if he judged by the number of jets "which are formed, and by the diſtance to "which they go.

* Recherches, p. 327. Phil. Tranſ. abridged, Vol. x. p. 382.

"3. If

"3. IF the tube be a capillary one, from "which the water only drops naturally, the "electrified jet not only becomes a continu- "ed stream, and even divided into several "streams, but is also considerably accelerat- "ed; and the smaller the capillary tube "is, the greater, in proportion, is this ac- "celeration.

"4. So great, is the effect of the electric "virtue, that it drives the water in a con- "stant stream out of a very small capillary "tube, out of which it had not before been "able even to drop."

THE most unaccountable of these experiments, as the ingenious Abbé acknowledges, are those which suppose a retardation of the electrified current, and he long doubted the fact; but a great number of experiments, carefully noted in his journal, obliged him to admit it, though still with hesitation, and to account for it in the best manner he could; which, indeed, is not very satisfactory *.

THE beautiful appearance of these streams of electrified water, when the experiment was exhibited in the dark, is particularly described by this author, after Messrs. Boze and Gordon, who first observed it †.

THESE last experiments served as a basis to the Abbé's future inquiries. He considered all organized bodies as assemblages of capillary tubes, filled with a fluid that tends to run through them, and often to issue out of them.

* Recherches, p. 351. † Ibid. p. 354.

In

In conſequence of this idea, he imagined, that the electric virtue might poſſibly communicate ſome motion to the ſap of vegetables, and alſo augment the inſenſible perſpiration of animals. He began with the following experiments, the reſult of which confirmed his ſuppoſition *.

He electrified for four or five hours together, fruits, green plants, and ſpunges, dipped in water which he had carefully weighed; and found that, after the experiment, all thoſe bodies were remarkably lighter than others of the ſame kind, weighed with them, both before and after the experiment, and kept in the ſame place and temper †.

The electrification of growing vegetables was firſt begun in Britain. Mr. Maimbray at Edinburgh electrified two myrtle trees, during the whole month of October 1746; when they put forth ſmall branches and bloſſoms ſooner than other ſhrubs of the ſame kind, which had not been electrified. Mr. Nollet, hearing of this experiment, was encouraged to try it himſelf ‡.

He took two garden pots, filled with the ſame earth, and ſowed with the ſame ſeeds. He kept them conſtantly in the ſame place, and took the ſame care of them; except that one of the two was electrified fifteen days together, for two or three, and ſometimes four hours a day. The conſequence was, that the

* Recherches, p. 355.
† Phil Tranſ. abridged, Vol. x. p. 383.
‡ Recherches, 356.

electri-

electrified pot always shewed the sprouts of its seeds two or threee days sooner than the other. It also threw out a greater number of shoots, and those longer in a given time; which made him believe, that the electric virtue helped to open and display the germs, and thereby to facilitate the growth of plants. This, however, our cautious philosopher only calls a conjecture, which required farther confirmation. The season, he says, was then too far advanced to allow him to make as many experiments as he could have wished, but he says the next course of experiments had greater certainty, and they are not less interesting *.

THE same experiments were carrying on about the same time by Mr. Jallabert, Mr. Boze, and the Abbé Menon, principal of the college of Bueil at Angers, who all drew the same conclusions from them †.

THE Abbé chose several pairs of animals of different kinds, cats, pigeons, chaffinches, sparrows, &c. All these he put into separate wooden cages, and weighed them. One of each pair he electrified for five or six hours together, and then weighed them again. The result was, that the electrified cat was commonly sixty-five or seventy grains lighter than the other, the pigeon from thirty-five to thirty-eight grains, the chaffinch or sparrow six or seven grains. In order to have nothing to charge upon the difference that

* Recherches, p. 358, &c. Phil. Trans. abridged, Vol. x. p. 383. † Recherches, p. 357.

might

might arise from the temperament of the individuals he happened to pitch upon, he repeated the same experiments, by electrifying that animal of each pair which had not been electrified before; and, notwithstanding some small varieties the electrified animal was constantly lighter than the other in proportion *.

After these experiments, he had no doubt but that electricity increased the insensible perspiration of animals, but it was not certain whether this increase was in the ratio of their bulks, or in that of their surfaces. The Abbé's opinion was, that it was neither in the one, nor the other, strictly speaking, but in a ratio much more nearly approaching the latter than the former; so that he imagined, there was no room to apprehend, that a human person electrified would lose near a fiftieth part of his weight, as it appeared to him to have happened to one sort of bird; nor 140th part, as to the pigeon, &c. All that he had then observed upon that head was, that a young man or woman, between the ages of twenty and thirty, from being electrified five hours together, had lost several ounces of their weight, more than they were wont to lose when they were not electrified †.

The Abbé observes, that no inconvenience whatever was felt by the persons who submitted to be electrified in this manner. They

* Recherches, p. 366, &c.

† Phil. Transf. abridged, Vol, x. p. 384. Recherches, p. 382.

only

only found themselves a little exhausted, and had got a better appetite. He adds, that none of them found themselves sensibly warmer, and that he could not perceive that their pulse was encreased *.

THESE last experiments on human bodies, he justly observes, are difficult to pursue with exactness, because the cloathing, which cannot strictly be compared to the hairs or feathers of animals, retains a considerable share of the perspired matter, and prevents our forming a good judgment of the whole effect of the electric virtue.

THE foregoing experiments, he says, convinced him of the reality of the *effluent* matter, carrying away with it the perspirable parts of bodies, and what could be evaporated from their surfaces. And he was convinced of the *affluent* matter, by observing all those effects produced, if, instead of electrifying bodies themselves, they were only brought near a large body which was electrified. He moistened a thick spunge in water, and cut it into two pieces, and then weighed the parts separately, and placing the whole near a large electrified body; he found that, after an electrification of five or six hours, that part of the spunge which was nearer to the electrified body had lost more weight than the other. From this fact he concluded, that if any part of an animal body was presented to a large electrified substance, it would perspire more

* Recherches, p. 389.

than

than the other, and that perhaps obſtructions might by this means be removed from the pores of it *.

The experiments above recited of Mr. Nollet by no means ſatisfied the Engliſh philoſophers, and particularly Mr. Ellicott, who made experiments to refute the theory which the author had deduced from them. He obſerved that the ſyphon, though electrified, would only deliver the water by drops, if the baſon in which the water was contained was electrified too. But this does not invalidate Mr. Nollet's curious experiments upon the ſubject of evaporation and perſpiration. For when an animal body is electrified, there is always non-electric matter enough in the atmoſphere, to anſwer the purpoſe of the unelectrified baſon, in the experiment of the capillary tube; thereby to cauſe a continual exhalation of the perſpirable matter from the pores of the ſkin. Beſides, the capillary tube will, in fact, unite the water in a conſtant ſtream, when it has only the open air to throw it into. In all debates upon ſubjects in natural philoſophy, facts ought only to be oppoſed to facts. The veracity of the Abbé Nollet is not to be called in queſtion; though it muſt be acknowledged, that, in his later writings, at a time when his favourite ſyſtem was in danger, he makes miſtakes with reſpect to the facts that nearly affect it.

* Phil. Tranſ. abridged, Vol. x. p. 385.

To account for the appearance of light, which ſeems, in ſome caſes, to iſſue from a non-electric body preſented to an excited electric, and which Mr. Nollet thought to be the affluent matter, Mr. Ellicott ſuppoſes that it was the light which had come from the electric. In accounting for the ſuſpenſion of leaf gold between an electrified and an unelectrified plate, Mr. Ellicott's theory made it neceſſary to ſuppoſe (what Dr. Franklin afterwards found not to be fact) that the leaf gold will always be ſuſpended nearer the unelectrified than the electrified plate.

In his anſwer to Mr. Nollet, Mr. Ellicott alſo endeavours to account for the electric matter iſſuing from a point at the extremity of the conductor, more ſenſibly than if it had terminated round or flat. He ſays that the effluvia, in ruſhing from the globe along the conductor, as they approached the point, were brought nearer together, and therefore were denſer there than in any part of the rod. Conſequently, he ſays, if the light be owing to the denſity and velocity of the effluvia, it will be viſible at the point, and no where elſe. This, as far as I can find, was the firſt attempt to account for this phenomenon; but it by no means accounts for the whole virtue of the conductor being diſſipated from ſuch points. Indeed, it is no wonder that the influence of points which are but imperfectly underſtood even at this day, furniſhed too difficult a problem ſo many years ago*.

* Phil. Tranſ. abridged, Vol. x. p. 393.

It will, now, be universally acknowledged, that there was very great merit in these experiments of the Abbé Nollet, made upon animal and other organized bodies. He opened a new and noble field of electrical discoveries, and he pursued them with great attention, perseverance, and expence. This last circumstance, I suppose, may have been the reason why his experiments have not, as far as I can find, been resumed and pursued by any electrician since his time, though there seems to be great room to improve upon what he began. The only method in which they can be conducted to any purpose, would be by the the help of a machine for perpetual electrification, to go by wind or water; which would, likewise, serve for many other capital experiments in electricity. This application of electricity, in particular, may perhaps be of more use in medicine, than any other mode in which it has hitherto been administered.

Mr. Jallabert of Geneva carried the experiments on plants farther than the Abbé Nollet had done; and, by electrifying bottles in which the plants were growing in water, and placing in the same exposure other bottles, containing plants of the same kind; he proved, in the clearest manner, that the electrified plants always grew faster, and had finer stems, leaves, and flowers than those which were not electrified, and consumed more of their water *.

* Beccaria dell' elettricismo naturale et artificiale, p. 125.

SECTION

SECTION V.

THE HISTORY OF THE MEDICATED TUBES, AND OTHER COMMUNICATIONS OF MEDICINAL VIRTUES BY ELECTRICITY, WITH THEIR VARIOUS REFUTATIONS.

IN the courſe of this hiſtory we have ſeen frequent inſtances of ſelf-deception, for want of perſons attending to all the eſſential circumſtances of facts; but nothing we have yet ſeen equals what was exhibited in the years 1747 and 1748. Mr. Grey's deceptions were chiefly owing to his miſtaking the cauſe of real appearances; but in this caſe we can hardly help thinking, that, not only the imagination and judgment, but even all the external ſenſes of philoſophers muſt have been impoſed upon. It was aſſerted by Signior Pivati at Venice (who has all the merit of theſe extraordinary diſcoveries), and, after him, by Mr. Verati at Bologna, Mr. Bianchi at Turin, and Mr. Winckler at Leipſick, that if odorous ſubſtances were confined in glaſs veſſels, and the veſſels excited, the odours and other medicinal virtues would tranſpire through the glaſs, infect the atmoſphere of the conductor, and communicate the virtue to all perſons in contact with it; alſo that thoſe ſubſtances, held in the hands of perſons electrified, would communicate their virtues to them; ſo that medicines might be made to

operate without being taken into the ſtomach. They even pretended to have wrought many cures by the help of electricity applied this way. Some of the more curious of theſe pretended experiments deſerve to be recorded, for the entertainment and inſtruction of poſterity.

THE forementioned Signior Johannes Franciſco Pivati, a perſon of eminence at Venice, ſays, in an Italian epiſtle, printed at Venice with all the uſual licences, in the year 1747, that a manifeſt example of the virtue of electricity was ſhown in the balſam of Peru, which was ſo concealed in a glaſs cylinder, that, before the excitation of it, not the leaſt ſmell could by any means be diſcovered. A man who, having a pain in his ſide, had applied hyſſop to it, by the advice of a phyſician, approached the cylinder thus prepared, and was electrified by it. The conſequence was, that when he went home, and fell aſleep, he ſweated, and the power of the balſam was ſo diſperſed, that even his cloaths, the bed, and chamber, all ſmelled of it. When he had refreſhed himſelf by his ſleep, he combed his head, and found the balſam to have penetrated his hair; ſo that the very comb was perfumed *.

The next day, Signior Pivati ſays, he electrified a man in health in the ſame manner, who knew nothing of what had been done before. On his going into company half an hour

* Phil. Tranſ. abridged, Vol. x. p. 400.

hour afterwards, he found a gradual warmth diffuſing itſelf through his whole body, and he grew more lively and chearful than uſual. His companion was ſurpriſed at an odour, and could not imagine whence it proceeded, but he himſelf perceived that the fume aroſe from his own body, at which he alſo was much ſurpriſed, not having the leaſt ſuſpicion that it was owing to the operation which had been performed upon him by Signior Pivati *.

MR. WINCKLER of Leipſick, being ſtruck with ſo extraordinary a relation, ſays, that he was deſirous of trying the power of electricity on certain ſubſtances in the ſame manner, and that he found the event to confirm what had been related †.

HE put ſome pounded ſulphur into a glaſs ſphere, ſo well covered and ſtopped, that, on turning it over the fire, there was not the leaſt ſmell of ſulphur perceived. When the ſphere was cold he electrified it; and, immediately, a ſulphureous vapour iſſued from it, and, on continuing the electricity, filled the air, ſo as to be ſmelled at the diſtance of more than ten feet. He called in a friend well verſed in electricity, profeſſor Haubold, and ſeveral others, as witneſſes and judges of this fact; but they were preſently driven away by the ſtench of the ſulphur. He ſtaid a little longer himſelf in this ſulphureous atmoſphere, and was ſo impregnated thereby, that his body, cloaths, and breath retained

* Phil. Tranſ. abridged, Vol. x. p. 401. † Ibid.

the odour even the next day. On repeating this experiment in the presence of a person who was conversant with the effects of sulphur, the signs of an inflamed blood were visible in his mouth on the third day *.

AFTER this he tried the effect of a more agreeable smell, and filled the sphere with cinnamon. When he had heated this as before, the smell of cinnamon was soon perceived by the company, and the whole room was in a short ime so perfumed by it, that it immediately affected the noses of all who came in, and the odour remained the next day.

HE tried the balsam of Peru with the like success, when his above mentioned friend (whose testimony, he says, he did not care to be without) after he had received the power of the balsam, smelled so strong of it, that going abroad to supper, he was often asked by the company what prefume he had about him. The next day, when Mr. Winckler was drinking tea, he says, he found an unusual sweet taste, owing to the fumes of the balsam that still remained in his mouth †.

IN a few days, when the sphere had lost all the scent of the balsam, they let a chain out of the chamber window, and extended it through the open air, into another room detached from the former. Here they suspended the chain on silken lines, and gave it into the hand of a man, who also stood on extended silken lines, and knew nothing of their

* Phil. Transf. abridged, Vol. x, p. 401. † Ibid.

purpose.

purpofe. When the electricity had been excited for fome time, the man was afked whether he fmelled any thing; and, on fnuffing up his nofe, he faid he did. Being afked again what fmell it was, he faid he did not know. When the electrification had been continued for about a quarter of an hour, the room fmelled fo ftrong of it, that the man, who knew nothing of the balfam, faid his nofe was filled with a fweet fmell, like that of fome fort of balfam. After fleeping in a houfe, a confiderable diftance from the room where the experiment was tried, he rofe very chearfully in the morning, and found a more pleafant tafte than ordinary in his tea *.

I SHALL only give an account of two inftances of the effect of medicine applied in this manner. The affiftance of Signior Pivati, the celebrated inventor of this improvement in electricity, was implored by a young gentleman, who was miferably afflicted by a quantity of corrupted matter collected in his foot, that eluded all the attempts of the phyficians. Signior Pivati filled a glafs cylinder with proper materials; and, having electrified it, drew fparks from the part affected, and continued the operation for fome minutes. When the patient went to bed, he had a good night, and a mitigation of his pain. When he awaked in the morning, he found a fmall red tubercle on his foot, which only itched, as if a cold humour had flowed through the

* Phil. Tranf. abridged, Vol. x. p. 401.

inner part of his foot. He ſweated every night for eight days together, and at the end of that time was perfectly well.

AFTER this, Signior Donadoni, biſhop of Sebenico, came to Signior Pivati, attended by his phyſician and ſome friends. His lordſhip was at that time ſeventy-five years old, and had been afflicted with pains in his hands and feet for ſeveral years. The gout had ſo affected his fingers, that he was not able to move them; and his legs, ſo that he could not bend his knees. In this deplorable ſituation, the poor old biſhop intreated Signior Pivati to try the effects of electricity on him. The electrician undertook it, and proceeded after the following manner. He filled a glaſs cylinder with diſcutient medicines, and managed it ſo, that the electric virtue might enter into the patient, who preſently felt ſome unuſual commotions in his fingers; and the action of electricity had been continued but two minutes, when his lordſhip opened and ſhut both his hands, gave a hearty ſqueeze to one of his attendants, got up, walked, ſmote his hands together, helped himſelf to a chair, and ſat down, wondering at his own ſtrength, and hardly knowing whether it was not a dream. At length he walked out of the chamber down ſtairs, without any aſſiſtance, and with all the alacrity of a young man *.

* Philoſophical Tranſactions abridged, Vol. x. p. 403.

A VARI-

A VARIETY of facts of this nature being published, and seemingly well attested, engaged all the electricians of Europe to repeat these experiments; but none of them could succeed but those mentioned above. An excellent remark of Mr. Baker's, who advised trying all these experiments, notwithstanding their seeming very improbable, deserves to be quoted here. "Romantic as these things "may seem, they should not be absolutely "condemned without a fair trial, since we "all, I believe remember the time, when "those phenomena in electricity, which are "now the most common and familiar to us, "would have been thought deserving as little "credit as the cases under consideration may "seem to do, had accounts of them been sent "to us from Rome, Venice, or Bologna, "and had we never experienced them our-"selves *."

To see these wonders, and to be assured of their truth or fallacy, Mr. Nollet, who was deeply interested in every thing that related to his favourite study, and who set no bounds to his labour or expences, in the pursuit of truth, even passed the Alps, and travelled into Italy, where he visited all the gentlemen who had published any account of these experiments. But though he engaged them to repeat their experiments in his presence, and upon himself; and though he made it his business to get all the best information he could

* Phil. Transf. abridged, Vol. x. p. 406.

concerning

concerning them, he returned, convinced that the accounts of cures had been much exaggerated; that in no one inftance had odours been found to tranfpire through the pores of excited glafs; and that no drugs had ever communicated their virtues to perfons who only held them in their hands while electrified.

He had no doubt, however, but that, by continued electrification, without drugs, feveral perfons had found confiderable relief in various diforders; particularly, that a paralytic perfon had been cured at Geneva, and that a perfon deaf of one ear, a footman who had a violent pain in his head, and a woman who had a diforder in her eyes, were cured at Bologna *.

The Englifh philofophers fhowed no lefs attention to this fubject than the Abbé Nollet. The Royal Society had received an account from Mr. Winckler of his experiments, to prove the tranfudation of odoriferous matter through the pores of excited glafs; and none of them fucceeding here, the fecretary was defired to write to Mr. Winckler, in the name of the fociety, defiring him to tranfmit to them, not only a circumftantial account of his manner of making the experiments, but likewife fome globes and tubes, fitted up by himfelf, for that purpofe.

These veffels, and directions how to ufe them, Mr. Winckler actually fent, and the

* Phil. Tranf. abridged, Vol. x. p. 413, &c.

experi-

experiments were made with every poſſible precaution, at the houſe of Dr. Watſon (the moſt intereſted and active perſon in the kingdom in every thing relating to electricity) on the 12th of June 1751. There were preſent Martin Folkes, preſident of the Royal Society, Nicholas Mann, Eſq. vice preſident, Dr. Mortimer, and Peter Daval, Eſq. ſecretaries, Mr. Canton a fellow, and Mr. Shroder, a gentleman of diſtinction, well known to, and correſponding with Mr. Winckler. But, notwithſtanding all the pains theſe gentlemen took, purſuing, with the utmoſt exactneſs, the directions of Mr. Winckler, and alſo uſing methods of their own, which they thought ſtill better adapted to force the effluvia through the glaſs, they were unſucceſsful. They were not able to verify Mr. Winckler's experiments even in one ſingle inſtance *.

But perhaps the moſt ſatisfactory refutation both of this pretended tranſudation of odours, and the medicinal effects of electricity above mentioned, was made at Venice, the very place where this medical electricity took its riſe. The experiments were made by Dr. Bianchini, profeſſor of medicine, in the preſence of a great number of witneſſes, many of them prejudiced in favour of the pretended diſcoveries; but they were all forced to be convinced of their futility, by the evidence of facts, and by experiments made with the greateſt care and accuracy †.

* Phil. Tranſ. abridged, Vol. xlvii. p. 321.
† Ibid. Vol. xlviii. p. 399.

AFTER

AFTER the publication of these accounts properly attested, every unprejudiced person was satisfied, that the pretended discoveries from Italy and Leipsick, which had raised the expectation of all the electricians in Europe, had no foundation in fact; and that no method had yet been discovered whereby the power of medicine could by electricity be made to insinuate itself into the human body *.

LASTLY, I would observe, that Dr. Franklin also showed, by several experiments, the impossibility of mixing the effluvia or virtue of medicines with the electric fluid †.

IN some respects similar to the experiments with the *medicated tubes* (as those mentioned above were usually called) was that of professor Boze, which he termed the *beatification*; and which, for a long time, employed other electricians to repeat after him, but to no purpose. His description of this famous experiment was, that if, in electrifying, large globes were employed, and the electrified person were placed upon large cakes of pitch, a lambent flame would by degrees arise from the pitch, and spread itself round his feet; and that from thence it would be propagated to his knees and body, till, at last, it ascended to his head; that then, by continuing the electrification, the person's head would be surrounded by a glory, such a one, in some

* Phil. Transf. abridged, Vol. xlviii. p. 406.
† Franklin's Letters, p. 82.

measure,

meaſure, as is repreſented by painters in their ornamenting the heads of ſaints *.

THIS experiment, as well as that of the medicated tubes, ſet all the electricians in Europe to work, and put them to a great deal of expence; but none of them could ſucceed, ſo as to produce an appearance any thing like that deſcribed by Mr. Boze. No perſon took more pains in this buſineſs than Dr. Watſon. He himſelf underwent the operation ſeveral times, ſupported by ſolid electrics three feet high. Upon being electrified very ſtrongly, he found, as he ſays ſeveral other perſons alſo did, a tingling upon the ſkin of his head, and in many parts of his body, or ſuch a ſenſation as would be felt from a vaſt number of inſects crawling over him at the ſame time; and he conſtantly obſerved the ſenſation to be the greateſt in thoſe parts of his body which were neareſt to any non-electric, but ſtill no light appeared upon his head, though the experiment was ſeveral times made in the dark, and with ſome continuance †.

AT length the Doctor, wearied with theſe fruitleſs attempts, wrote to the profeſſor, and his anſwer ſhowed that the whole had been a mere trick. He candidly acknowledged, that he had made uſe of a ſuit of armour, which was decked with many bullions of ſteel, ſome pointed like nails, ſome like wedges, and ſome pyramidal; and that when the electrization was very vigorous, the edges of the

* Phil. Tranſ. abridged, Vol. x. p. 411. † Ibid.

helmet

helmet would dart forth rays, something like those which are painted on the heads of saints. And this was all his boasted beatification *.

THIS same Mr. Boze, who seems to have had a singular affectation of something mysterious and marvellous in his experiments, in a letter to the Royal Society at London, said that he had been able, by electricity only, to invert the poles of a natural magnet, to destroy their virtue, and to restore it again, but he did not describe his method †. Considering that no person in England could succeed in this attempt, and that we are now able to do it but imperfectly, it is hardly probable that he did it at all.

THERE seems to have been some deception in an experiment which the worthy and excellent Dr. Hales communicated to the Royal Society this year, when he says, that he observed the electric spark from warm iron to be of a bright light colour; from warm copper, green; and from a warm egg, of a yellowish flame colour, These experiments, he said, seemed to argue, that some particles of those different bodies were carried off in the electric flashes, whence those different colours were exhibited ‡.

I SHALL conclude this section, which might justly be intitled the *marvellous*, with

* Phil. Transf. abridged, Vol. x. p. 413.
† Wilson's Essay, p. 219.
‡ Phil. Transf. abridged, Vol. x. p. 406.

mention-

mentioning the surprising effect of an electric spark in setting fire to a fustian frock, on a son of Mr. Robert Roche, when he was electrified for some disorder. I do not question the fact. The experiment was repeated, and it answered again as well as at the first time, when it was merely accidental. The paper containing this account was read at the Royal Society on the 29th of May 1743 *.

PERIOD IX.

THE EXPERIMENTS AND DISCOVERIES OF DR. FRANKLIN.

SECTION I.

DR. FRANKLIN'S DISCOVERIES CONCERNING THE LEYDEN PHIAL, AND OTHERS CONNECTED WITH THEM.

WE have hitherto seen what had been done in electricity by the English philosophers, and those on the continent of Europe, till about the year 1750; but our attention is now strongly called to what was doing on the continent of America; where Dr. Franklin and his friends were as assiduous in trying experiments, and as successful in

* Phil. Transf. abridged, Vol. x. p. 406.

making

making discoveries, as any of their brethren in Europe. For this purpose, we must look back a few years. As Dr. Franklin's discoveries were made intirely independent of any in Europe, I was unwilling to interrupt the former general account, by introducing them in their proper year. For the same reason, I imagine, it will be generally more agreeable, to see, at one view, what was done in America for some considerable space of time, without interrupting this account with what was doing, in the mean time, in Europe. I shall, therefore, digest, in the best manner I can, the three first publications of Dr. Franklin, entitled *New Experiments and Observations on Electricity, made at Philadelphia in America*, communicated in several letters to Peter Collinson, Esq. of London, fellow of the Royal Society; the first of which is dated July 28th, 1747, and the last April 18th, 1754.

NOTHING was ever written upon the subject of electricity which was more generally read and admired in all parts of Europe than these letters. There is hardly any European language into which they have not been translated; and, as if this were not sufficient to make them properly known, a translation of them has lately been made into Latin. It is not easy to say, whether we are most pleased with the simplicity and perspicuity with which these letters are written, the modesty with which the author proposes every hypothesis of his own, or the noble frankness with which he relates his mistakes, when they

they were corrected by subsequent experiments.

THOUGH the English have not been backward in acknowledging the great merit of this philosopher, he has had the singular good fortune to be, perhaps even more celebrated abroad than at home; so that to form a just idea of the great and deserved reputation of Dr. Franklin, we must read the foreign publications on the subject of electricity; in many of which the terms *Franklinism*, *Franklinist*, and the *Franklinian system* occur in almost every page. In consequence of this, Dr. Franklin's principles bid fair to be handed down to posterity, as expressive of the true principles of electricity; just as the Newtonian philosophy is of the true system of nature in general.

THE zeal of Dr. Franklin's friends, and his reputation, were considerably increased by the opposition which the Abbé Nollet made to his theory. The Abbé, however, never had any considerable seconds in the controversy, and those he had, I am informed, have all deserted him.

THE rise of Dr. Franklin's fame in France was first occasioned by a bad translation of his letters falling into the hands of Mr. Buffon, intendant of the French King's gardens, and author of the Natural History for which he is famous. This gentleman, having successfully repeated Dr. Franklin's experiments, engaged a friend of his, Mr. Dalibard, to revise the translation; which was afterwards publish-

ed, with a ſhort hiſtory of electricity prefixed to it, and met with a very favourable reception from all ranks of people. What contributed not a little to the ſucceſs of this publication, and to bring Dr. Franklin's principles into vogue in France, was a friend of Mr. Dalibard's exhibiting Dr. Franklin's experiments for money. All the world, in a manner, flocked to ſee theſe new experiments, and all returned full of admiration for the inventor of them *.

Dr. Franklin had diſcovered, as well as Dr. Watſon, that the electric matter was not created, but collected by friction, from the neighbouring non-electric bodies. He had obſerved, that it was impoſſible for a man to electrify himſelf, though he ſtood upon glaſs or wax; for that the tube could communicate to him no more electricity than it had received from him in the act of excitation. He had obſerved, that if two perſons ſtood upon wax, one of which rubbed the tube, and the other took the fire from it, they would both appear to be electrified; that if they touched one another after that operation, a ſtronger ſpark would be perceived between them, than when any other perſon touched either of them; and that ſuch a ſpark would take away the electricity of both †.

These experiments led the Doctor to think, that the electric fluid was conveyed from the perſon who rubbed the tube to him who touch-

* Nollet's Letters, Vol. i. p. 4.
† Franklin's Letters, p. 14.

ed

ed it; which introduced ſome terms in electricity that had not been uſed before, but have continued in uſe ever ſince. The perſon who touched the tube was ſaid, by Dr. Franklin, to be electrified *poſitively*, or *plus*; being ſuppoſed to receive an additional quantity of electric fire: whereas the perſon who rubbed the tube was ſaid to be electrified *negatively*, or *minus*; being ſuppoſed to have loſt a part of his natural quantity of the electric fluid *.

THIS obſervation was neceſſary to explain the capital diſcovery which Dr. Franklin made with reſpect to the manner of charging the Leyden phial; which is, that when one ſide of the glaſs is electrified poſitively, or *plus*, the other ſide is electrified negatively, or *minus*; ſo that whatever quantity of fire is thrown upon one ſide of the glaſs, the ſame is thrown out of the other; and there is really no more electric fire in the phial after it is charged than before; all that can be done by charging, being to take from one ſide, and convey to the other. Dr. Franklin alſo obſerved, that glaſs was impervious to electricity, and that, therefore, ſince the equilibrium could not be reſtored to the charged phial by any internal communication, it muſt be done by conductors externally, joining the inſide and the outſide †.

THESE capital diſcoveries he made by obſerving, that when a phial was charged, a cork ball ſuſpended on ſilk would be attracted

* Franklin's Letters, p. 15. † Ibid. p. 3.

by the outside coating, when it was repelled by a wire communicating with the inside; and that it would be repelled by the outside, when it was attracted by the inside*. But the truth of this maxim appeared more evident when he brought the knob of the wire communicating with the outside coating within a few inches of the wire communicating with the inside coating, and suspended a cork ball between them; for, in that case, the ball was attracted by them alternately, till the phial was discharged †.

The European electricians had observed, that a phial could not be charged unless some conductor was in contact with the outside; but Dr. Franklin made the observation more general, and also was able, by the principle above mentioned, to give a better account of it. As no more electric fire, he says, can be thrown into the inside of a phial when all is driven from the outside; so, in a phial not yet charged, none can be thrown into the inside when none can be got from the outside. He also showed, by a beautiful experiment, that, when the phial was charged, one side lost exactly as much as the other gained, in restoring the equilibrium. Hanging a small linen thread near the coating of an electrified phial, he observed, that every time he brought his finger near the wire, the thread was attracted by the coating. For as the fire was taken from the inside by touching the

* Franklin's Letters, p. 4. † Ibid. p. 5.

wire, the outſide drew in an equal quantity by the thread *.

He proved that, in diſcharging the phial, the giving from one ſide was exactly equal to the receiving by the other, by placing a perſon upon electrics, and making him diſcharge the phial through his body; when he obſerved, that no electricity remained in him after the diſcharge †. He alſo hung cork balls upon an inſulated conductor at the time of the diſcharge of a phial hanging to it; and obſerved, that if they did not repel before the exploſion, they did not repel at the time, nor after ‡. But the experiment which moſt completely proved, that the coating on one ſide received juſt as much as was emitted from the diſcharge of the other, was the following.

He inſulated his rubber, and then, hanging a phial to his conductor, he found it could not be charged, even though his hand was held conſtantly to it; becauſe, though the electric fire might leave the outſide of the phial, there was none collected by the rubber to be conveyed into the inſide. He then took away his hand from the phial, and forming a communication, by a wire from the outſide coating to the inſulated rubber, he found that it was charged with eaſe. In this caſe, it was plain, that the very ſame fire which left the outſide coating was conveyed by the way of the rubber, the globe, the conductor,

* Franklin's Letters, p. 5. † Ibid p. 8.
‡ Ibid. p. 84.

and the wire of the phial, into the inside *.

DR. FRANKLIN's new theory of charging the Leyden phial led him to obſerve a greater variety of facts, relating both to charging and diſcharging it, than other philoſophers had attended to. He found that the phial would be electrified as ſtrongly if it were held by the hook, and the coating applied to the globe or tube, as if it were held by the coating, and the hook applied; and, conſequently, that there would be the ſame exploſion, and ſhock, if the electrified phial were held in one hand by the hook, and the coating touched with the other, as when held by the coating, and touched at the hook. To take the charged phial by the hook with ſafety, and not diminiſh its force, he obſerves, that it muſt firſt be ſet down upon electrics per ſe †.

DR. FRANKLIN obſerved, that if a man held in his hand two phials, the one fully electrified, and the other not at all, and brought their hooks together, he would have but half a ſhock: for the phials would both remain only half electrified, the one being half charged, and the other half diſcharged ‡.

IF two phials were charged both through their hooks, a cork ball ſuſpended on ſilk, and hanging between them, would firſt be attracted, and then repelled by both; but if they were electrified, the one through the

* Franklin's Letters, p. 83. † Ibid. p. 19.
‡ Ibid. p. 21.

wire,

wire, and the other through the coating, the ball would play vigorously between them both, till they were nearly discharged *. The Doctor did not, at that time, take notice, that if the phials were both charged through their coatings (by which both the hooks would have been electrified minus) the ball would be repelled by them both, as when they were electrified plus. And when he, afterwards, observed that two bodies electrified minus repelled one another, he seems to have been surprised at the appearance, and acknowledged that he could not satisfactorily account for it †.

It was known to every electrician, that a globe or tube wet on the inside would afford little or no fire; but no good reason was given for it, before Dr. Franklin attempted its explanation by the help of his general maxim. He says, that when a tube lined with any non-electric is rubbed, what is collected from the hand by the downward stroke enters the pores of the glass, driving an equal quantity out of the inner surface, into the non-electric lining; and that the hand, in passing up to take a second stroke, takes out again what had been thrown into the outward surface, the inner surface at the same time receiving back again what it had given to the non-electric lining; so that the particles of the electric fluid go in and out of their pores, upon every stroke given to the tube ‡.

* Franklin's Letters, p. 21. † Ibid. p. 34.
‡ Ibid. p. 76.

IF, in theſe circumſtances, a wire was put into the tube, he obſerved, that, if one perſon touched the wire, while another was rubbing the tube, and took care to withdraw his finger as ſoon as he had taken the ſpark, which had been made to fly from the inſide, it would be charged *.

IF the tube was exhauſted of air, he obſerves, that a non-electric lining in contact with the wire was not neceſſary; for that, in vacuo, the electric fire would fly freely from the inner ſurface, without a non-electric conductor †.

UPON the ſame principle he accounts for the effects of an excited electric being perceived through the glaſs in the vacuum beyond it. The tube and its excited atmoſphere, being brought near a glaſs veſſel, repels the electric fluid from the inner ſurface of the glaſs; and this fluid, iſſuing from the inner ſurface acts upon light bodies in the vacuum, both in its paſſage from the glaſs, and likewiſe in its return to it, when the excited electric on the outſide is withdrawn ‡.

THIS maxim, that whatever the phial takes in at one ſurface it loſes at the other, led Dr. Franklin to think of charging ſeveral phials together with the ſame trouble, by connecting the outſide of one with the inſide of another; whereby the fluid that was driven out of the firſt would be received by the ſecond,

* Franklin's Letters, p. 77. † Ibid.
‡ ibid p. 78.

and

and what was driven out of the ſecond would be received by the third, &c. By this means he found, that a great number of bottles might be charged with the ſame labour as one only; and that they might be charged equally high, were it not that every bottle receives the new fire, and loſes its old with ſome reluctance, or rather gives ſome ſmall reſiſtance to the charging. This cirumſtance, he ſays, in a number of bottles, becomes more equal to the charging power, and ſo repels the fire back again on the globe ſooner than a ſingle bottle would do *.

Upon this principle Dr. Franklin conſtructed an *electrical battery*, conſiſting of eleven panes of large ſaſh glaſs, coated on each ſide, and ſo connected, that charging one of them would charge them all. Then having a contrivance to bring all the giving ſides in contact with one wire, and all the receiving ſides with another, he united the force of all the plates, and diſcharged them all at once †.

When Dr. Franklin firſt began his experiments upon the Leyden phial, he imagined that the electric fire was all crowded into the ſubſtance of the non-electric in contact with the glaſs; but he afterwards found, that its power of giving a ſhock lay in the glaſs itſelf, and not in the coating, by the following ingenious analyſis of the bottle.

In order to find where the ſtrength of the charged bottle lay, he placed it upon glaſs;

* Franklin's Letters, p. 12. † Ibid. p. 26.

then

then first took out the cork and the wire, and finding the virtue was not in them; he touched the outside coating with one hand, and put the finger of the other into the mouth of the bottle; when the shock was felt quite as strong as if the cork and wire had been in it. He then charged the phial again, and pouring out the water into an empty bottle insulated, expected that if the force resided in the water it would give the shock, but he found it gave none. He then judged that the electric fire must either have been lost in decanting, or must remain in the bottle; and the latter he found to be true; for, filling the charged bottle with fresh water, he found the shock, and was satisfied that the power of giving it resided in the glass itself *.

THE Doctor made the same experiment with panes of glass, laying the coating on lightly, and changing it, as he had before changed the water in the bottle, and the result was the same in both †. This experiment is more satisfactory than the former; because, when the water is poured out of the phial, there still remains a thin coating of the fluid, which might be thought to contain the power of giving a shock.

THAT the electric fire resided in the glass, was also farther evident from this consideration, that when glass was gilt, the discharging of it would make a round hole, tearing off a part of the gilding, which, the Doctor

* Franklin's Letters p. 24. † Ibid. p 25.

thought,

thought, could only have been done by the fire coming out of the glaſs through the gilding. He alſo ſays, that when the gilding was varniſhed even with turpentine, this varniſh, though dry and hard, would be burned by the ſpark driven through it, yielding a ſtrong ſmell, and a viſible ſmoke. Alſo, that when a ſpark was driven through paper, it would be blackened by the ſmoke, which ſometimes penetrated ſeveral of the leaves, and that part of the gilding which had been torn off was found forcibly driven into the hole made in the paper by the ſtroke. He alſo obſerved, that when a thin bottle was broken by a charge, the glaſs was broken inwards, at the ſame time that the gilding was broken outwards *.

LASTLY, Dr. Franklin diſcovered, that ſeveral ſubſtances which would conduct electricity in general, would not conduct the ſhock of a charged phial. A wet packthread, for inſtance, though it tranſmitted electricity very well, ſometimes failed to conduct a ſhock; as alſo did a cake of ice. Dry earth too rammed into a glaſs tube intirely failed to conduct a ſhock, and indeed would convey electricity but very imperfectly †.

* Franklin's Letters, p. 32. † Ibid. p. 33.

SECTION II.

DR. FRANKLIN'S DISCOVERIES CONCERNING THE SIMILARITY OF LIGHTNING AND ELECTRICITY.

THE greateſt diſcovery which Dr. Franklin made concerning electricity, and which has been of the greateſt practical uſe to mankind, was that of the perfect ſimilarity between electricity and lightning. The analogy between theſe two powers had not been wholly unobſerved by philoſophers, and eſpecially by electricians, before the publication of Dr. Franklin's diſcovery. It was ſo obvious, that it had ſtruck ſeveral perſons. I ſhall give one inſtance, in the ſagacious Abbé Nollet.

THE Abbé ſays*, "If any one ſhould "take upon him to prove, from a well con-"nected compariſon of phenomena, that "thunder is, in the hands of nature, what "electricity is in ours, that the wonders "which we now exhibit at our pleaſure are "little imitations of thoſe great effects which "frighten us, and that the whole depends "upon the ſame mechaniſm; if it is to be de-"monſtrated, that a cloud, prepared by the "action of the winds, by heat, by a mix-"ture of exhalations, &c. is oppoſite to a

* Leçons de Phyſique, Vol. iv. p. 34.

terreſtrial

"terreſtrial object; that this is the electrized "body, and, at a certain proximity from "that which is not; I avow that this idea, if "it was well ſupported, would give me a "great deal of pleaſure; and in ſupport of "it, how many ſpecious reaſons preſent "themſelves to a man who is well acquaint-"ed with electricity. The univerſality of the "electric matter, the readineſs of its action, "its inflammability, and its activity in giv-"ing fire to other bodies, its property of "ſtriking bodies externally and internally, "even to their ſmalleſt parts, the remarkable "example we have of this effect in the ex-"periment of Leyden, the idea which we "might truly adopt in ſuppoſing a greater "degree of electric power, &c. all theſe "points of analogy, which I have been ſome "time meditating, begin to make me be-"lieve, that one might, by taking electrici-"ty for the model, form to one's ſelf, in re-"lation to thunder and lightning, more per-"fect and more probable ideas than what "have been offered hitherto, &c."

Mr. Winckler alſo enumerated many particulars, in which electricity and lightning reſemble one another *.

But though the Abbé, and others, had been ſtruck with the obvious analogy between lightning and electricity, they went no farther than theſe arguments *a priori*. It was Dr. Franklin who firſt propoſed a method of

* Dantzick Memoirs, Vol. iii. p. 528.

verifying

verifying this hypothesis, entertaining the bold thought, as the Abbé Nollet expresses it, of bringing lightning from the heavens, of thinking that pointed iron rods, fixed in the air, when the atmosphere was loaded with lightning, might draw from it the matter of the thunderbolt, and discharge it without noise or danger into the immense body of the earth, where it would remain as it were absorbed.

MOREOVER, though Dr. Franklin's directions were first begun to be put in execution in France, he himself completed the demonstration of his own problem, before he heard of what had been done elsewhere: and he extended his experiments so far as actually to imitate almost all the known effects of lightning by electricity, and to perform every electrical experiment by lightning.

BUT before I relate any of Dr. Franklin's experiments concerning lightning, I must take notice of what he observed concerning the power of *pointed bodies*, by means of which he was enabled to carry his great designs into execution. For he was properly the first who observed the intire and wonderful effect of pointed bodies, both in drawing, and throwing off the electric fire.

IT was a small step towards discovering the effect of pointed bodies, that Carolus Augustus van Bergen, professor of medicine at Frankfort on the Oder, observed that sparks taken from a polished body were stronger than those from a rough one. He could fire spirit easily

with a polished conductor, but with difficulty by means of one not polished*.

Mr. Jallabert was perhaps the first who observed that a body, pointed at one end, and round at another, produced different appearances upon the same body, according as the pointed, or round end was presented to it. But as Mr. Nollet, in whose presence he made the experiment, says, the effect was not constant, and nothing was inferred from it †. And the Abbé acknowledges, that Dr. Franklin was the first who showed the property of pointed bodies, in drawing off electricity more effectually, and at greater distances than other bodies could do it ‡.

He electrified an iron shot, three or four inches in diameter, and observed, that it would not attract a thread, when the point of a needle was presented to it; but that this was not the case, unless the pointed body had a communication with the earth; for, presenting the same pointed body, stuck on a piece of sealing-wax, it had not that effect; though the moment the pointed body was touched with his finger, the electricity of the ball to which it was suspended was discharged. The

* Dantzick Memoirs, Vol. ii. p. 378.

† Lettres, Vol. i. p. 130.

‡ Recherches, p. 132. Dr. Franklin, in the new edition of his Letters, p. 5, says, that the power of points to throw off the electric fire, was communicated to him by his friend Mr. Thomas Hopkinson, who electrified an iron ball of three or four inches diameter, with a needle fastened to it, expecting to draw a stronger spark from the point, as from a kind of focus, but was surprised to find little or none.

converse

converſe of this he proved, by finding it impoſſible to electrify the iron ſhot when a ſharp needle lay upon it *.

By obſerving points of different degrees of acuteneſs, Dr. Franklin corrected the concluſion of Mr. Ellicott, and other Engliſh electricians, that a pointed body, as a piece of leaf gold, would always be ſuſpended nearer to the plate which was unelectrified than that which was electrified, if it were put between them. For the Doctor obſerved, that it always removed fartheſt from that plate to which its ſharpeſt point was preſented, whether it was electrified or not; and if one of the points was very blunt, and the other very ſharp, it would be ſuſpended in the air by its blunt end, near the electrified body, without any unelectrified plate being held below it at all †.

Dr. Franklin endeavoured to account for this effect of pointed bodies, by ſuppoſing that the baſe on which the electric fluid at the point of an electrified body reſted, being ſmall, the attraction by which the fluid was held to the body was ſlight; and that, for the ſame reaſon, the reſiſtance to the entrance of the fluid was proportionably weaker in that place than where the ſurface was flat ‡. But he himſelf candidly owns, that he was not quite ſatisfied with this hypotheſis. Whatever we think of Dr. Franklin's theory of the influence of pointed conductors in

* Franklin's Letters, p. 56, &c. † Ibid. p. 67.
‡ Ibid. p. 56.

drawing

drawing and throwing off the electric fluid, the world is greatly indebted to him for the practical use he made of this doctrine *.

The manner in which Dr. Franklin first conceived the practicability of drawing lightning from the clouds may be seen in an extract which he has given us from his memorandums, November 7th, 1749. After enumerating all the known points of resemblance between lightning and electricity, he concludes with saying, "The electric fluid is at-"tracted by points. We do not know whether "this property be in lightning, but since they "agree in all the particulars in which we can "already compare them, it is not probable that "they agree likewise in this. Let the experi-"ment be made." Every circumstance relating to a discovery of so much importance as this, is interesting and pleasing †.

Dr. Franklin begins his account of the similarity of the electric fluid and lightning by cautioning his readers not to be staggered at the great difference of the effects in point of degree; since that is no argument of any disparity in their nature. It is no wonder, says he, if the effects of the one should be so much greater than those of the other. For if two gun barrels electrified will strike at two inches distance, and make a loud report, at how great a distance will ten thousand acres of electrified cloud strike, and give

* Franklin's Letters, p. 62.
† Letters, New Edit. p. 323.

its fire, and how loud muſt be that crack * !

I SHALL digeſt all Dr. Franklin's obſervations concerning lightning under the ſeveral points of reſemblance which he obſerved between it and electricity, mentioned theſe points of ſimilarity in the order in which he himſelf remarked them; only bringing into one place the obſervations which may happen to lie in different parts of his letters, when they relate to the ſame ſubject.

1. FLASHES of lightning, he begins with obſerving, are generally ſeen crooked, and waving in the air. The ſame, ſays he, is the electric ſpark always, when it is drawn from an irregular body at ſome diſtance †. He might have added, when it is drawn by an irregular body, or through a ſpace in which the beſt conductors are diſpoſed in an irregular manner, which is always the caſe in the heterogeneous atmoſphere of our globe.

2. LIGHTNING ſtrikes the higheſt and moſt pointed objects in its way preferably to others, as high hills, and trees, towers, ſpires, maſts of ſhips, points of ſpears, &c. In like manner, all pointed conductors receive or throw off the electric fluid more readily than thoſe which are terminated by flat ſurfaces ‡.

3. LIGHTNING is obſerved to take the readieſt and beſt conductor. So does electri-

* Franklin's Letters, p. 44. † Ibid. p. 46.
‡ Ibid. p. 47.

city

city in the discharge of the Leyden phial. For this reason, the Doctor supposes that it would be safer, during a thunder storm, to have one's cloaths wet than dry, as the lightning might then, in a great measure, be transmitted to the ground, by the water, on the outside of the body. It is found, says he, that a wet rat cannot be killed by the explosion of the electrical bottle, but that a dry rat may *.

4. LIGHTNING burns. So does electricity. Dr. Franklin says, that he could kindle with it hard dry rosin, spirits unwarmed, and even wood. He says, that he fired gun-powder, by only ramming it hard in a cartridge, into each end of which pointed wires were introduced, and brought within half an inch of one another, and discharging a shock through them †.

5. LIGHTNING sometimes dissolves metals. So does electricity, though the Doctor was mistaken when he imagined it was by a cold fusion, as will appear in its proper place. The method in which Dr. Franklin made electricity melt metals was by putting thin pieces of them between two panes of glass bound fast together, and sending an electric shock through them. Sometimes the piece of glass, by which they were confined, would be shattered to pieces by the discharge, and be broken into a kind of coarse sand, which once happened with pieces of thick looking-glass; but if they remained whole, the piece

* Franklin's Letters, p. 47. † Ibid. p. 48, 92.

of metal would be miſſing in ſeveral places where it had lain between them, and inſtead of it, a metallic ſtain would be ſeen on both the glaſſes, the ſtains on the under and upper glaſs being exactly ſimilar in the minuteſt ſtroke *.

A PIECE of leaf gold treated in this manner appeared not only to have been melted, but, as the Doctor thought, even vitrified, or otherwiſe ſo driven into the pores of the glaſs, as to be protected by it from the action of the ſtrongeſt aqua regis. Sometimes he obſerved that the metallic ſtains would ſpread a little wider than the breadth of the thin pieces of metal. True gold, he obſerved, made a darker ſtain, ſomewhat reddiſh, and ſilver a greeniſh ſtain †.

MR. WILSON ſuppoſes that, in this experiment, the gold was not driven into the pores of the glaſs, but only into ſo near a contact with the ſurface of the glaſs, as to be held there by an exceedingly great force; ſuch an one, he ſays, as is exerted at the ſurface of all bodies whatever ‡.

6. LIGHTNING rends ſome bodies. The ſame does electricity §. The Doctor obſerves, that the electric ſpark would ſtrike a hole through a quire of paper. When wood, bricks, ſtone, &c. are rent by lightning, he takes notice, that the ſplinters will fly off on that ſide where there is the leaſt reſiſtance.

* Franklin's Letters, p. 48, 65. † Ibid. p. 68.
‡ Hoadley and Wilſon, p. 68.
§ Franklin's Letters, p. 49.

In

In like manner, he ſays, when a hole is ſtruck through a piece of paſteboard by an electrified jar, if the ſurfaces of the paſteboard are not confined and compreſſed, there will be a bur raiſed all round the hole on both ſides of the paſteboard; but that if one ſide be confined, ſo that the bur cannot be raiſed on that ſide, it will all be raiſed on the other ſide, which way ſoever the fluid was directed. For the bur round the outſide of the hole is the effect of the exploſion, which is made every way from the center of the electric ſtream, and not an effect of its direction *.

7. LIGHTNING has often been known to ſtrike people blind. And a pigeon, after a violent ſhock of electricity, by which the Doctor intended to have killed it, was obſerved to have been ſtruck blind likewiſe †.

8. IN a thunder ſtorm at Stretham, deſcribed by Dr. Miles ‡, the lightning ſtripped off ſome paint which had covered a gilded molding of a pannel of wainſcot, without hurting the reſt of the paint. Dr. Franklin imitated this, by paſting a ſlip of paper over the filleting of gold on the cover of a book, and ſending an electric flaſh through it. The paper was torn off from end to end, with ſuch force, that it was broken in ſeveral places; and in others there was brought away part of the grain of the Turkey leather in which the book was bound. This convinced

* Franklin's Letters, p. 124. † Ibid. p. 63.
‡ Phil. Tranſ. abridged, Vol. xlv, p. 387.

the Doctor, that if it had been paint, it would have been ſtripped off in the ſame manner with that on the wainſcot at Stretham *.

9. LIGHTNING deſtroys animal life. Animals have likewiſe been killed by the ſhock of electricity. The largeſt animals which Dr. Franklin and his friends had been able to kill were a hen, and a turkey which weighed about ten pounds †.

10. MAGNETS have been obſerved to loſe their virtue, or to have their poles reverſed by lightning. The ſame did Dr. Franklin by electricity. By electricity he frequently gave polarity to needles, and reverſed them at pleaſure. A ſhock from four large jars, ſent through a fine ſewing needle, he ſays, gave it polarity, ſo that it would traverſe when laid on water. What is moſt remarkable in theſe electrical experiments upon magnets is, that if the needle, when it was ſtruck, lay Eaſt and Weſt, the end which was entered by the electric blaſt pointed North, but that if it lay North and South, the end which lay towards the North, would continue to point North, whether the fire entered at that end or the contrary; though he imagined, that a ſtronger ſtroke would have reverſed the poles even in that ſituation, an effect which had been known to have been produced by lightning. He alſo obſerved, that the polarity was ſtrongeſt when the needle was ſtruck ly-

* Phil. Tranſ. abridged, Vol. xlv. p. 64.
† Franklin's Letters, p. 86, 153.

ing

ing North and South, and weakeſt when it lay Eaſt and Weſt. He takes notice that, in theſe experiments, the needle, in ſome caſes, would be finely blued, like the ſpring of a watch, by the electric flame; in which caſe the colour given by a flaſh from two jars only might be wiped off, but that a flaſh from four jars fixed it, and frequently melted the needles. The jars which the Doctor uſed held ſeven or eight gallons, and were coated and lined with tinfoil *.

To demonſtrate, in the completeſt manner poſſible, the ſameneſs of the electric fluid with the matter of lightning, Dr. Franklin, aſtoniſhing as it muſt have appeared, contrived actually to bring lightning from the heavens, by means of an electrical kite, which he raiſed when a ſtorm of thunder was perceived to be coming on. This kite had a pointed wire fixed upon it, by which it drew the lightning from the clouds. This lightning deſcended by the hempen ſtring, and was received by a key tied to the extremity of it; that part of the ſtring which was held in his hand being of ſilk, that the electric virtue might ſtop when it came to the key. He found that the ſtring would conduct electricity even when nearly dry, but that when it was wet, it would conduct it quite freely; ſo that it would ſtream out plentifully from the key, at the approach of a perſon's finger †.

* Franklin's Letters, p 90, &c. † Ibid. p. 106.

At this key he charged phials, and from electric fire thus obtained, he kindled ſpirits, and performed all other electrical experiments which are uſually exhibited by an excited globe or tube.

As every circumſtance relating to ſo capital a diſcovery as this (the greateſt, perhaps, that has been made in the whole compaſs of philoſophy, ſince the time of Sir Iſaac Newton) cannot but give pleaſure to all my readers, I ſhall endeavour to gratify them with the communication of a few particulars which I have from the beſt authority,

The Doctor, after having publiſhed his method of verifying his hypotheſis concerning the ſameneſs of electricity with the matter lightning, was waiting for the erection of a ſpire in Philadelphia to carry his views into execution; not imagining that a pointed rod, of a moderate height, could anſwer the purpoſe; when it occurred to him, that, by means of a common kite, he could have a readier and better acceſs to the regions of thunder than by any ſpire whatever. Preparing, therefore, a large ſilk handkerchief, and two croſs ſticks, of a proper length, on which to extend it, he took the opportunity of the firſt approaching thunder ſtorm to take a walk into a field, in which there was a ſhed convenient for his purpoſe. But dreading the ridicule which too commonly attends unſucceſsful attempts in ſcience, he communicated his intended experiment to no body but

but his ſon, who aſſiſted him in raiſing the kite.

The kite being raiſed, a conſiderable time elapſed before there was any appearance of its being electrified. One very promiſing cloud had paſſed over it without any effect; when, at length, juſt as he was beginning to deſpair of his contrivance, he obſerved ſome loſe threads of the hempen ſtring to ſtand erect, and to avoid one another, juſt as if they had been ſuſpended on a common conductor. Struck with this promiſing appearance, he immediately preſented his knucle to the key, and (let the reader judge of the exquiſite pleaſure he muſt have felt at that moment) the diſcovery was complete. He perceived a very evident electric ſpark. Others ſucceeded, even before the ſtring was wet, ſo as to put the matter paſt all diſpute, and when the rain had wetted the ſtring, he collected electric fire very copiouſly. This happened in June 1752, a month after the electricians in France had verified the ſame theory, but before he had heard of any-thing that they had done.

Besides this kite, Dr. Franklin had afterwards an inſulated iron rod to draw the lightning into his houſe, in order to make experiments whenever there ſhould be a conſiderable quantity of it in the atmoſphere; and that he might not loſe any opportunity of that nature, he connected two bells with this apparatus, which gave him notice,

 by

by their ringing, whenever his rod was electrified *.

THE Doctor being able, in this manner, to draw the lightning into his house, and make experiments with it at his leisure; and being certain that it was in all respects of the same nature with electricity, he was desirous to know if it was of the positive or negative kind. The first time he succeeded in making an experiment for this purpose was the 12th of April 1753, when it appeared that the lightning was negative. Having found that the clouds electrified negatively in eight successive thunder gusts, he concluded they were always electrified negatively, and formed a theory to account for it. But he afterwards found he had concluded too soon. For, on the sixth of June following, he met with one cloud which was electrified positively; upon which he corrected his former theory, but did not seem able perfectly to satisfy himself with any other. The Doctor sometimes found the clouds would change from positive to negative electricity several times in the course of one thunder gust, and he once observed the air to be strongly electrified during a fall of snow, when there was no thunder at all †.

BUT the grand practical use which Dr. Franklin made of his discovery of the sameness of electricity and lightning, was to se-

* Franklin's Letters, p. 112. † Ibid. p. 112, &c.

cure

cure buildings from being damaged by lightning, a thing of vast consequence in all parts of the world, but more especially in several parts of North America, where thunder storms are more frequent, and their effects, in that dry air, more dreadful, than they are ever known to be with us.

This great end Dr. Franklin accomplished by so easy a method, and by so cheap, and seemingly trifling apparatus, as fixing a pointed metalline rod higher than any part of the building, and communicating with the ground, or rather the nearest water. This wire the lightning was sure to seize upon, preferably to any other part of the building; whereby this dangerous power would be safely conducted to the earth, and dissipated, without doing any harm to the building *.

Dr. Franklin was of opinion, that a wire of a quarter of an inch in thickness would be sufficient to conduct a greater quantity of lightning than was ever actually discharged from the clouds in one stroke. He found, that the gilding of a book was sufficient to conduct the charge of five large jars, and thought, that it would probably have conducted the charge of many more. He also found by experiment, that if a wire was destroyed by an explosion, it was yet sufficient to conduct that particular stroke, though it was thereby rendered incapable of conducting another †.

* Franklin's Letters, p. 62, 124. † Ibid. p. 124, 125.

The Doctor alſo ſuppoſed, that pointed rods erected on edifices might likewiſe often prevent a ſtroke of lightning in the following manner. He ſays, that an eye ſo ſituated as to view horizontally the underſide of a thunder cloud, will ſee it very ragged, with a number of ſeparate fragments, or petty clouds, one under another, the loweſt ſometimes not far from the earth. Theſe, as ſo many ſtepping ſtones, aſſiſt in conducting a ſtroke between a cloud and a building. To repreſent theſe by an experiment, he directs us to take two or three locks of fine looſe cotton and connect one of them with the prime conductor, by a fine thread of two inches (which may be ſpun out of the ſame lock) another to that, and a third to the ſecond, by like threads. He then bids us to turn the globe, and ſays we ſhall ſee theſe locks extending themſelves towards the table (as the lower ſmall clouds do towards the earth) but, that, on preſenting a ſharp point, erect under the loweſt, it will ſhrink up to the ſecond, the ſecond to the firſt, and all together to the prime conductor, where they will continue as long as the point continues under them. A moſt ingenious and beautiful experiment! May not, he adds, in like manner, the ſmall electrified clouds, whoſe equilibrium with the earth is ſoon reſtored by the point, riſe up to the main body, and by that means occaſion ſo large a vacancy, as that the grand cloud cannot ſtrike in that place *.

* Franklin's Letters, p. 121, &c.

Mr.

Mr. Wilcke, in his remarks on Dr. Franklin's letters, ſays, that on the 2[illegible]th of Auguſt 1758, he ſaw this ſuppoſition verified; as he was viewing a large fringed cloud, ſtrongly electrified, paſſing over a foreſt of tall fir trees. The ragged and depending parts of the large cloud were firſt attracted lower, and then ſuddenly roſe higher, and joined the large cloud *.

He was alſo an eye witneſs of two clouds lying one over the other, approaching, and flaſhing into one another. The lightning ſpread itſelf over all the parts of the blacker cloud, which was negative, and which immediately began to diſſolve in rain †.

Dr. Franklin adviſes perſons who are apprehenſive of danger from lightning, to ſit in the middle of a room (provided it be not under a metal luſtre ſuſpended by a chain) ſitting on one chair, and laying their feet on another. It is ſtill ſafer, he ſays, to bring two or three mattreſſes, or beds, into the middle of the room, and folding them double, to place the chairs upon them, for they not being ſo good conductors as the walls, the lightning will not chuſe to paſs through them; but the ſafeſt place of all is in a hammock hung in ſilken cords, at an equal diſtance from all the ſides of the room, p. 484. I would add, that the place of moſt abſolute ſafety muſt be the cellar, and eſpecially the middle of it; for when a perſon is lower than

* Wilcke's Tranſlation, p. 351.

† Franklin's Letters, p. 259.

the

the ſurface of the earth, the lightning muſt ſtrike it before it can poſſibly reach him. In the fields, the place of ſafety is, within a few yards of a tree, but not quite near it.

SECTION III.

MISCELLANEOUS DISCOVERIES OF DR. FRANKLIN, AND HIS FRIENDS IN AMERICA, DURING THE SAME PERIOD.

DR. FRANKLIN, retaining the common opinion, that electrified bodies have real atmoſpheres of the electric fluid (conſiſting of particles at ſome diſtance from the ſurface of the body, but always going along with it) obſerved that theſe atmoſpheres and the air did not ſeem to exclude one another; though, he ſays, this be diffiult to conceive, conſidering that they are generally ſuppoſed to repel one another.

AN electric atmoſphere, he ſays, raiſed round a thick wire, inſerted into a phial, drives out none of the air it contained; nor on withdrawing that atmoſphere, will any air ruſh in, as he found by a very curious experiment, accurately made; whence he alſo concluded, that the elaſticity of the air was not affected by it *.

THE experiment, as the Doctor informs me, was made with a ſmall glaſs ſyphon,

* Franklin's Letters, p. 98.

one

one leg paſſing through the cork into the bottle. The other leg had in it a drop of red ink, which readily moved on the leaſt change of heat or cold in the air contained in the phial; but not at all on the air's being electrified.

HE alſo made an experiment which would ſeem to prove the immobility, as we may ſay, of theſe atmoſpheres by any external force, if they have any exiſtence at all; but others may think it is rather an argument againſt their exiſtence. He electrified a large cork ball faſtened to the end of a ſilk ſtring three feet long; and, taking the other end in his hand, he whirled it round, like a ſling, a hundred times in the open air, with the ſwifteſt motion he could poſſibly give it; and obſerved, that it ſtill retained its electric atmoſphere, though it muſt have paſſed through eight hundred yards of air *.

To ſhow that a body, in different circumſtances of dilatation and contraction, is capable of receiving, or retaining more or leſs of the electric fluid on its ſurface, he made the following curious experiment. He electrified a ſilver cann, in which there were about three yards of braſs chain, one end of which he could raiſe to what height he pleaſed, by means of a pully and a ſilken cord. He ſuſpended a lock of cotton by a ſilken ſtring from the ceiling of the room, making it hang near the cup; and obſerved, that every time he drew up the

* Franklin's Letters, p. 97.

chain

chain, the cotton approached nearer to the cup, and as conſtantly receded from it when the chain was let down. From this experiment it was evident, he ſays, that the atmoſphere about the cup was diminiſhed by raiſing the chain, and increaſed by lowering it; and that the atmoſphere of the chain muſt have been drawn from that of the cup when it was raiſed, and have returned to it again when it was let down *.

To make electric atmoſpheres in ſome meaſure viſible, the Doctor uſed to drop roſin on hot iron plates held under bodies electrified; and, in a ſtill room, the ſmoke would aſcend, and form viſible atmoſpheres round the bodies, making them look very beautiful. In trying in what circumſtances, the repellency between an electrified iron ball, and a ſmall cork ball would be altered, he obſerved, that the ſmoke of roſin did not deſtroy their repellency, but was attracted both by the iron and the cork †.

The Doctor obſerved, that ſilver expoſed to the electric ſpark would acquire a blue ſtain, and that iron would ſeem corroded by it; but he could never perceive any impreſſion made on gold, braſs, or tin. The ſpots on the ſilver or iron were always the ſame, whether they received the ſpark from lead, braſs, gold, or ſilver; and the ſmell of the electric fire was the ſame, through whatever bodies it was conveyed ‡.

* Franklin's Letters, p. 121. † Ibid. p. 55.
‡ Ibid. p. 81, 98.

WHILE

While we are attending to what was done by Dr. Franklin at Philadelphia, we must by no means overlook what was done by Mr. Kinnersley, the Doctor's friend, while at Boston in New England. Some of his observations, of which an account is given in the Doctor's letters, are very curious; and some later accounts, which he himself has transmitted to England, seem to promise, that, if he continue his electrical inquiries, his name, after that of his friend, will be second to few in the history of electricity.

He first distinguished himself by re-discovering Mr. Du Fay's two contrary electricities of glass and sulphur, with which both he and Dr. Franklin were at that time wholly unacquainted. But Mr. Kinnersley had a great advantage over Mr. Du Fay; for making his experiments in a more advanced state of the science, he saw immediately, that the two contrary electricities of glass and sulphur were the very same positive and negative electricities, which had just been discovered by Dr. Watson and Dr. Franklin.

He observed, that a cork ball, electrified by a conductor from excited glass, would be attracted by excited amber and sulphur, and repelled by excited glass and china; that electrifying the ball with the wire of a charged phial, it would be repelled by excited glass, but attracted by excited sulphur; and that when he electrified it by sulphur or amber, till it became repelled by them, it would be attracted by the wire of the phial, and repelled by its

coating. These experiments surprised him very much, but by analogy he was led to infer, *a priori*, the following paradoxes, as he calls them, which were afterwards verified by Dr. Franklin at his request *.

"1. If a glass globe be placed at one end "of a prime conductor, and a sulphur one at "the other, both being equally in good or-"der, and in equal motion, not a spark of "fire can be obtained from the conductor, "but one globe will draw out as fast as the "other gives in.

"2. If a phial be suspended on the con-"ductor with a chain from its coating to the "table, and only one of the globes be made "use of at a time, twenty turns of the wheel, "for instance, will charge it; after which, "as many turns of the other wheel will "discharge it; and as many more will charge "it again.

"3. The globes being both in motion, "each having a separate conductor, with a "phial suspended on one of them, and the "chain fastened to the other; the phial will "become charged, one globe charging posi-"tively, and the other negatively.

"4. The phial being thus charged, hang "it in like manner, on the other conductor. "Set both wheels a-going again, and the "same number of turns that charged it be-"fore will now discharge it, and the same "number repeated will charge it again.

* Franklin's Letters, p. 99.

"5. When

"5. WHEN each globe communicates with "the same prime conductor, having a chain "hanging from it to the table, one of them, "when in motion (but which I cannot say) "will draw fire up through the cushion, and "discharge it, through the chain; and the "other will draw it up through the chain, "and discharge it through the cushion *."

WHEN Mr. Kinnersley was advising his friend to try the experiments with the sulphur globe, he cautions him not to make use of chalk on the cushion, telling him that some fine powdered sulphur would do better. And he expresses his hope that if the Doctor should find the two globes to charge the prime conductor differently, he would be able to discover some method of determining which it was that charged positively.

DR. FRANKLIN, when these experiments and conjectures were proposed to him, had no idea of their having any real foundation; but imagined, that the different attractions and repulsions observed by Mr. Kinnersley proceeded rather from the greater or smaller quantities of the electric fire, obtained from different bodies, than from its being either of a different kind, or having a different direction. But finding, upon trial, that the principal of Mr. Kinnersley's suppositions were verified by fact, he had no doubt of the rest †.

* Franklin's Letters, p. 100.
† Ibid. p. 102, 103.

In anſwer to the doubt of Mr. Kinnerſley, whether the glaſs, or the ſulphur electrified poſitively, the Doctor gave it as his opinion, that the glaſs globe charged poſitively, and the ſulphur negatively, for the following reaſons.

1. Because, though the ſulphur globe ſeemed to work equally well with the glaſs one, yet it could never occaſion ſo large, and ſo diſtant a ſpark between his finger and conductor as when the glaſs globe was uſed. But what he adds to confirm this proof does not ſeem to be ſatisfactory. He ſuppoſes that bodies of a certain bigneſs cannot ſo eaſily part with the quantity of electric fluid which they have, and hold attracted within their ſubſtance, as they can receive an additional quantity upon their ſurface, by way of atmoſphere; and that therefore ſo much could not be drawn out of the conductor, as might be thrown on it *.

2. He obſerved that the ſtream or bruſh of fire, appearing at the end of the wire connected with the conductor, was long, large, and much diverging when the glaſs globe was uſed, and made a ſnapping or rattling noiſe; but that when the ſulphur globe was uſed, it was ſhort, ſmall, and made a hiſſing noiſe. He alſo obſerved, that juſt the reverſe of both theſe caſes happened when he held the ſame wire in his hand, and the globes were worked alternately. The bruſh was large,

* Franklin's Letters, p. 104.

long,

long, diverging, and ſnapping or rattling, when the ſulphur globe was turned; bu ſhort, ſmall, and hiſſing, when the glaſs globe was turned. When the bruſh was long, large, and much diverging, it ſeemed to the Doctor, that the body to which it joined was throwing the fire out, and when the contrary appeared, it ſeemed to be drinking in *.

3. HE obſerved, that when he held his knuckle before the ſulphur globe, while it was turning, the ſtream of fire between his knuckle and the globe ſeemed to ſpread on its ſurface, as if it flowed from the finger, but before the glaſs globe it was otherwiſe.

4. He obſerved that the cool wind (or what was called ſo) which is felt as coming from an electrified point, was much more ſenſible when the glaſs globe, than when the ſulphur one was uſed. But theſe, though the beſt arguments which the ſenſes can furniſh, of the courſe of the electric fluid, the Doctor acknowledges were but haſty thoughts. Indeed, conſidering that the velocity of the electric fluid has been found, by experiment, to be nearly inſtantaneous, in a circuit of many miles, it cannot be ſuppoſed that the eye ſhould be able to diſtinguiſh which way it goes in the ſpace of one or two inches †.

I SHALL conclude this article with obſerving that the experiments, which the Doctor made with globes of glaſs and ſulphur, are

* Franklin's Letters, p. 104. † Ibid. p. 105.

much more easily exhibited by the conductor and insulated rubber of either of them, all the effects being the reverse of each other.

I MUST now, for the present, take leave of this ingenious writer and his friends, after having brought the history of their labours to the year 1754, and must return to see what was doing on the continent of Europe for two or three years preceding this date, while we left it to go over to America.

PERIOD X.

THE HISTORY OF ELECTRICITY, FROM THE TIME THAT DR. FRANKLIN MADE HIS EXPERIMENTS IN AMERICA, TILL THE YEAR 1766.

WE are now entering upon the last period into which the history of electricity divides itself, in which the great variety of matter presented to our view must oblige an historian to have recourse to the strictest method; for, otherwise, the narration would be extremely perplexed and disgusting. As this period contains the events of a larger space of time than most of the others, yet without any convenient resting place; as the business of electricity has been considerably multiplied in it, and a greater number of labourers have been employed in gathering in the harvest of discoveries, the seeds of which were sown by Dr. Watson, Dr. Franklin, and others,

others, in the preceding periods; I am obliged to ſubdivide this into more diſtinct parts, but I hope they will not be found to be more than were neceſſary, in order to prevent confuſion.

HOWEVER, this circumſtance, of the great quantity and variety of materials furniſhed in this period, in proportion as it tends to embarraſs an hiſtorian, and exerciſe his talent for proper diſtribution and arrangement, is a ſtriking demonſtration of a truth, which muſt give the greateſt pleaſure to all the lovers of electricity and Natural Philoſophy. If the progreſs continue the ſame in another period, of equal length, if the harveſt of diſcoveries continue to be more plentiful, and the labourers proportionably more numerous; what a glorious ſcene ſhall we ſee unfolded, what a fund of entertainment is there in ſtore for us, and what important benefits may be derived to mankind!

SECTION I.

IMPROVEMENTS IN THE ELECTRICAL APPARATUS, WITH EXPERIMENTS AND OBSERVATIONS RELATING TO IT.

AS our electrical apparatus has been much improved within this period, I shall first recite what has occurred to me upon this subject; particularly the methods which have, from time to time, been communicated of increasing the power of electricity, by different circumstances of excitation.

So early as the year 1751, upon occasion of trying Mr. Winckler's experiments, notice is taken of Mr. Canton's method of rubbing tubes with silk prepared with linseed oil. These he had found, by the experience of some considerable time, to produce the greatest effect upon tubes, but he had not found that they were proportionably useful in rubbing globes *.

UPON another occasion, Mr. Canton observes, that by means of this rubber, a solid cylinder of glass, which had been set before the fire till it was quite dry, might be excited as easily as a glass tube, so as to act like one in every respect; that even the first stroke would make it strongly electrical †.

* Phil. Transf. abridged, Vol. xlvii. p. 239.
† Ibid. Vol. xlviii. pt. ii. p. 784.

BUT

But the greateſt improvement which Mr. Canton diſcovered for increaſing the power of electricity, was by rubbing on the cuſhion of the globe, or on the oiled ſilk rubber of the tube, a ſmall quantity of an amalgam of mercury and tin, with a very little chalk or whiting. By this means, a globe or tube may be excited to a very great degree with very little friction, eſpecially if the rubber be made more damp or dry as occaſion may require *.

Mr. Wilcke ſays, that a glaſs tube excited with a woollen cloth, on which ſome white wax or oil has been put, will throw out flames with a great noiſe in the dark †. Theſe flames, he ſays, he never knew to be thrown from a globe, except ſometimes when they were firſt uſed ‡.

Our electrical apparatus has been much augmented within this period by the diſcovery of Father Windelinus Ammerſin of Switzerland, who, in a Latin treatiſe, publiſhed at Lucern, in the year 1754, has ſhewn us, that wood properly dried, till it becomes very brown, is a non-conductor of electricity. He recommends boiling the wood in linſeed oil, or covering it over with varniſh, after being dried, to prevent any return of moiſture into its pores; and adds, that wood, ſo treated, ſeems to afford ſtronger appearances of electricity than even glaſs. He himſelf made uſe of common wooden meaſures, ſuch as are

* Phil. Tranſ. Vol. lii. pt. ii. p. 461.
† Wilcke, p. 124. ‡ Ibid. p. 126.

usually

usually found in granaries, first boiled in oil, and afterwards mounted, so as to be turned by a wheel *.

It appears from the Philosophical Transactions, says Mr. Wilson, so early as the year 1747, that Dr. Watson having occasion to support a long wire, in an experiment made near Shooter's Hill, with a view to determine the velocity of electric fluid, used stakes of dry wood, which he told him, were baked, to prevent the electric fluid from escaping into the ground †.

A more extraordinary method of procuring electricity than by baked wood, was one that Signior Beccaria made use of. He put a dry and warm cat's skin upon his glass globe, and rubbing it with his hand, excited a very powerful electrity ‡.

These wooden cylinders electrify positively or negatively as the rubber is silk or flannel, but much more powerfully when negative than when positive, owing to the roughness which there generally is upon their surfaces, and therefore make an agreeable variety in an electrical apparatus. But the oldest and most usual method of procuring negative electricity was by globes of sulphur. These Mr. Le Roi made by putting a coating of sulphur upon a globe of glass, and then smoothing it with an hot iron; but Mr. Nollet preferred melting the sulphur in the inside

* Phil. Transf. Vol. lii. pt. i. p. 342.
† Ibid. Vol. li. pt. ii. p. 896.
‡ Lettere dell' Elettricismo, p. 58.

of

of the glafs globe, and then breaking the glafs from off it, becaufe this method made a much finer polifh *.

One globe he made of a mixture of fulphur and pounded glafs, but he found that it had the fame effect as if it had been all of fulphur. He fays that, when one part of this globe was excited, the whole furface became electrical †.

But fince Mr. Canton's difcovery of the negative power of rough glafs, fome philofophers have made ufe of glafs globes made rough by emery; and the ufual method of taking off their polifh was by rubbing them as they turned upon their axis; but Mr. Speedler, a mathematical inftrument maker at Copenhagen, obferves, in his letters upon the fubject of electricity, that glafs globes, made rough by drawing the ftone, or emery, from pole to pole, have a much greater virtue; this method of taking off the polifh giving them a greater roughnefs with refpect to the rubber ‡.

But a better, and a readier method than all thefe of producing negative electricity, is by infulating the rubber of a fmooth globe, and connecting it with an infulated prime conductor, while the common conductor hath a communication with the ground. The rubber, if well infulated, is fure to produce a negative electricity, equal in power to the pofitive of the fame globe. Mr. Dalibard directs a

* Nollet's Letters, Vol. ii. p. 121.

† Ibid. p. 125, 127.

‡ Wilcke, p. 57.

great

great number of precautions, in order to electrify well at the rubber, and to prevent it from receiving any electric fire in its state of insulation *.

Mr. Bergman of Upsal, says, that very often, when his glass globes could not be excited to a sufficient degree of strength, he lined them with a thin coating of sulphur, and that then they gave a much stronger positive electricity than before †.

In Italy, and other places, Mr. Nollet informs us, it is the custom of electricians to put a coating of pitch, or other resinous matter on the inside of their globes, which they pretend, makes them always work well ‡.

We are obliged to the Abbé Nollet for some observations on the electrical powers of different kinds of glass, in the sixth volume of his *Leçons de physique* printed in the year 1764.

It is not every sort of glass, says he, that is equally electrizable. There are some sorts which are not so at all, or hardly at all; such, for example, is that of which they make plates of glass at St. Gobin in Picardy. I have tried it, says he, an hundred times, in the form of plates, tubes, and globes, and in all kinds of weather, but have scarce been ever able to draw from it the least sensible sign of electricity.

* Dalibard's Franklin, p. 110.
† Phil. Trans. Vol. lii. pt. ii. p. 485.
‡ Lettres, Vol. ii. p. 122.

The

The glaſs of which panes for windows are made, and which is alſo uſed for drinking-glaſſes, when it is newly manufactured, is excited with great difficulty. I have often, ſays he, repeatedly rubbed tubes, and other pieces, even in the glaſs-houſe where they were made, but without ſucceſs; and it has not been till after ſome months, and ſometimes years, that I could bring them to act.

It is certain, and he ſays he has conſtantly obſerved, that glaſs becomes more fit for electrical experiments by force of rubbing and that ſometimes it has required ſome months to bring globes and tubes to act well.

He did not think that theſe facts could be accounted for either by the different degrees of tranſparency, or the different colours of glaſs. This, indeed, was evident from ſome globes acquiring electricity from uſe which had it not originally. The glaſs of which bottles are made at Severs ſerved him very well, whereas globes of white glaſs did not become tolerable till after having been uſed a certain time.

He could not tell poſitively why certain kinds of glaſs were electrizable or not by rubbing, but he ſuſpected, that it was principally owing to the degree of its hardneſs and vitrification. He was induced to think ſo, becauſe he found that the glaſs at the French manufactory at St. Gobin, and at Cherbourg (the hardeſt, the moſt compact, and the beſt vitrified of all the kinds of glaſs in France) was

was the moſt difficult to be electrized; whereas the cryſtal glaſs of England, that of Bohemia, &c. which are much ſofter, were the beſt of all for experiments in electricity. He ſays, moreover, that he had procured imperfect glaſſes, which had not been long enough in the furnace to be clear; and that, though they were of the ſame compoſition as plates of glaſs, which, he obſerved before, were not eaſily electrized, yet that theſe were excited very ſenſibly.

He ſays that a globe of ten or twelve inches diameter, and which makes about four revolutions in a ſecond of time, will receive a convenient rubbing; but that we muſt not expect that if the globe be one half, or one fourth part greater or leſs, the effects will be increaſed or diminiſhed in proportion *.

Upon the ſubject of inſulating bodies, he obſerves, that when the cakes of ſulphur, reſin, ſealing-wax, and bees-wax are made uſe of for this purpoſe, they ought to be well cooled before they are uſed: for, he ſays, he has conſtantly obſerved, that when they are newly made, they are not ſo proper to inſulate bodies, as they generally are at the end of ſome months †.

It will be proper, under this head, to acquaint young electricians, that globes have been ſeveral times known to burſt during the act of excitation, and that the fragments have been thrown with great violence in every di-

* Leçons de Phyſique, Vol. vi. p. 273—276.
† Ibid. p. 299.

rection,

rection, so as to be very dangerous for the by-standers. This accident happened to Mr. Sabatelli in Italy, Mr. Nollet in France, Mr. Beraud at Lyons, Mr. Boze at Wittemburgh, Mr. Le Cat at Rouen, and Mr. Robein at Rennes.

THE air in the inside of Mr. Sabatelli's globe had no communication with the externul air, but that of the Abbé Nollet had. This last, which was of English flint, which had been used two years, and which was more than a line thick, burst like a bomb in the hands of a servant who was rubbing it; and the fragments (the largest of which were not more than an inch in diameter) were dispersed on all sides, to a considerable distance. The Abbé says, that all the globes which were burst in that manner exploded after five or six turns of the wheel; and he ascribes this effect to the action of the electric matter, making the particles of the glass vibrate in a manner he could not conceive*.

WHEN Mr. Beraud's globe burst (and he was the first to whom this accident was ever known to happen) he was making some experiments in the dark, on the 8th of February 1750; when a noise was first heard, as of something rending to pieces; then followed the explosion, and when the lights were brought in, it was observed, that those places of the floor which were opposite to the equatorial diameter of the globe were strewed with

* Nollet's Letters, Vol. i. p. 19.

smaller

ſmaller pieces, and in greater numbers than thoſe which were oppoſite to other parts of it. This globe had been cracked, but it had been in conſtant uſe in that ſtate above a year, and the crack had extended itſelf from the pole to the equator. The proprietor aſcribed the accident to the vibration of the particles of the glaſs, and thought that the crack had ſome way impeded thoſe vibrations *.

When Mr. Boze's globe broke, he ſays that the whole of it appeared in the act of breaking, like a flaming coal; a circumſtance which we ſhall ſee accounted for hereafter by Mr. Wilcke †.

Mr. Boulanger ſays, that glaſs globes have ſometimes burſt like bombs, and have wounded many perſons, and that their fragments have even penetrated ſeveral inches into a wall ‡. He alſo ſays, that if globes burſt in whirling by the gun-barrel's touching them, they burſt with the ſame violence, the ſplinters often entering into the wall §.

The Abbé Nollet had a globe of ſulphur which alſo burſt, as he was rubbing it with his naked hands, after two or three turns of the wheel, having firſt cracked inwardly. It broke into very ſmall pieces, which flew to a great diſtance; and into a fine duſt, of which part flew againſt his naked breaſt; where it entered the ſkin ſo deep, that it could not be got off without the edge of a knife ||.

* Hiſtoire, p. 87. † Wilcke, p. 124.
‡ Boulanger, p. 23. § Ibid. p. 144.
|| Nollet's Letters, Vol. ii. p. 220.

2 SECTION

SECTION II.

OBSERVATIONS ON THE CONDCUTING POWER OF VARIOUS SUBSTANCES, AND PARTICULARLY MR. CANTON's EXPERIMENTS ON AIR; AND SIGNIOR BECCARIA's ON AIR, AND WATER.

ONE of the principal *desiderata* in the science of electricity, is to ascertain wherein consists the distinction between those bodies which are conductors, and those which are non-conductors of the electric fluid. All that has been done relating to this question, till the present time, amounts to nothing more than observations, how near these two classes of bodies approach one another; and before the period of which I am now treating, these observations were few, general, and superficial. But I shall now present my reader with several very curious and accurate experiments, which, though they do not give us intire satisfaction with respect to the great *desideratum* above mentioned; yet throw some light upon the subject. They show that substances which had been considered as perfect conductors, or non-conductors, are so only to a certain degree; and that, probably, all the known parts of nature have, in some measure, the properties of both.

THESE experiments were made by two persons, whom, in the style of history, I

may juſtly call two of the greateſt *heroes* of this part of my work, viz. Mr. CANTON, whoſe diſcoveries in electricity are far more numerous, and more conſiderable than thoſe of any other perſon, within this period, in England; and Signior BECCARIA, one of the moſt eminent of all the electricians abroad.

THAT air was capable of receiving electricity by communication, and of retaining it when received, had not been diſcovered by any perſon before Mr. Canton; but, by the help of one of his exquiſite contrivances, he was able to aſcertain that delicate circumſtance, and even meaſure the degree of it, if it was in the leaſt conſiderable.

HE got a pair of balls, turned in a lathe, out of the dry pith of elder. Theſe he put into a narrow box, with a ſliding cover, ſo diſpoſed that the threads (which were of the fineſt linen) were kept ſtraight in the box. Holding this box by the extremity of the cover, the balls would hang freely from a pin in the inſide. Theſe balls hung at a ſufficient diſtance from buildings, trees, &c. eaſily ſhow the electricity of the atmoſphere. They alſo determine whether the electricity of the clouds and the air be poſitive, by the decreaſe; or negative, by the increaſe of their repulſion, at the approach of excited amber or ſealing-wax.

BY the help of this inſtrument, he obſerved, that it was poſſible to electrify the air of a room near the apparatus; and even the

the air of the whole room in which it was, to a considerable degree, and he was able to do it both positively and negatively.

In a paper read at the Royal Society, December the 6th, 1753, he observes, that the common air of a room might be electrified to a considerable degree, so as not to part with its electricity for some time. Having rendered the air of his room very dry, by means of a fire, he electrified a tin tube (with a pair of balls suspended at one of its extremities) to a great degree; when it appeared, that the neighbouring air was likewise electrified. For, having touched the tube with his finger, or any other conductor, the balls, notwithstanding, continued to repel one another, though not at so great a distance as before*. But he observes that their repulsion would decrease as they were moved towards the floor, wainscot, or any of the furniture; and that they would touch each other when brought within a small distance of any conductor. Some degree of this electric power, he has known to continue in the air above an hour after the rubbing of the tube, when the weather had been very dry.

To electrify the air, or the moisture contained in it, negatively, Mr. Canton supported, by silk stretched between two chairs (placed back to back, at the distance of about three feet), a tin tube with a fine sewing needle at

* Phil. Transf. Vol. xlix. pt. I. p. 300.

one end of it; and rubbed ſulphur, ſealing-wax, or a rough glaſs tube as near as he could to the other end, for three or four minutes; after which he found the air to be negatively electrical, and that it would continue ſo a conſiderable time after the apparatus was removed into another room *.

In a paper dated November the 11th, 1754, he ſays, that dry air, at a great diſtance from the earth, if in an electric ſtate, will continue ſo till it meets with ſome conductor, is probable from the following experiment. An excited glaſs tube, with its natural poliſh, being placed upright in the middle of a room (by putting one end of it into an hole, made for that purpoſe, in a block of wood) would, generally, loſe its electricity in leſs than five minutes, by attracting to it a ſufficient quantity of moiſture, to conduct the electric fluid from all parts of its ſurface to the floor; but if, immediately after it was excited, it was placed, in the ſame manner, before a good fire, at the diſtance of about two feet, where no moiſture would adhere to its ſurface, it would continue electrical a whole day, and how much longer he knew not †.

Since the publication of the firſt edition of this work, Mr. Canton has hit upon another, much readier, and more powerful method of communicating electricity to the air than that deſcribed above. This he gives me

* Phil. Tranſ. Vol. xlviii. pt. ii. p. 784. † Ibid.

leave to publiſh, and it appears to me to be of ſuch a nature, as that it may very poſſibly lead to farther diſcoveries concerning the electricity of the atmoſphere, and the phenomena depending upon it. " Take," ſays he, " a charged phial in one hand, and a lighted " candle, inſulated, in the other; and, going " into any room, bring the wire of the phial " very near to the flame of the candle, and " hold it there about half a minute: then " carry the phial and candle out of the room, " and return with the pith balls, ſuſpended, " and held at arm's length. The balls will " begin to ſeparate on entering the room, " and will ſtand an inch and half, or two " inches a part, when brought near the " middle of it."

Signior Beccaria, who had no knowledge of what Mr. Canton had done, made the ſame diſcovery of the communication of electricity to the air, and diverſified the experiment in a much more pleaſing and ſatiſfactory manner. He proves, that the air, which is contiguous to an electrified body, acquires, by degrees, the ſame electricity; that this electricity of the air counteracts that of the body, and leſſens its effects, and that as the air acquires, ſo it alſo parts with this electricity very ſlowly.

He began his experiments by hanging linen threads upon an electrified chain, and obſerving, that they diverged the moſt after a few turns of his globe. After that, they came nearer together, notwithſtanding he

 kept

kept turning the globe and the excitation was as powerful as ever *.

When he had kept the chain electrified a confiderable time, and then difcontinued the friction, the threads collapfed by degrees, till they hung parallel. After this, they began to diverge again, without any frefh electrification; and, if the air was ftill, this fecond divergence would continue an hour, or more.

This divergence was leffened by the electrification of the chain. For if the globe was turned again, the threads would firft become parallel; and then begin to diverge again as before. Thus the fecond divergence of the threads took place, when the chain was deprived of its electricity, and when that which the air had acquired began to fhow itfelf.

While the threads were beginning to diverge with the electricity of the air, if he touched the chain, and thereby took off what remained of its electricity, the threads would feparate farther. Thus the more the electricity of the chain was leffened, the more did the electricity of the air appear.

While the threads were in their fecond divergence, he hung two other threads, fhorter than the former, by another filk thread to the chain; and when all the electricity of the chain was taken quite away, they would feparate, like the former threads.

* Lettere dell' Elettricifmo, p. 87.

If

If he presented other threads to the former, in their second divergence, they would all avoid one another *.

In this complete and elegant manner did Signior Beccaria demonstrate, that air actually receives electricity by communication, and loses it by degrees; and that the electricity of the air counteracts that of the body which conveys electricity to it.

Signior Beccaria also made a variety of other experiments, which demonstrate other mutual affections of the air and the electric fluid; particularly some that prove their mutual repulsion; and that the electric fluid, in passing through any portion of air, makes a temporary vacuum.

He brought the ends of two wires within a small distance of one another, in a glass tube, one end of which was closed, and the other immerged in water; and observed, that the water sunk in the tube, every time that a spark passed from the one to the other, the electric fluid having repelled the air †.

He made the electric explosion a great number of times, in the same air, inclosed in a glass tube, in order to ascertain whether the elasticity of the air was affected by it; but he could not find any alteration. After the operation, he broke the tube under water, but neither did any air make its escape, nor any water force its way into the tube. The expe-

* Lettere dell' Elettricismo, p. 90.

† Elettricismo artificiale e naturale, p. 110.

riment was made with all the precaution, with respect to heat and cold, that the nature of the case required *.

SIGNIOR BECCARIA's experiments on *water*, showing its imperfection as a conductor, are more surprising than those he made upon air, showing its imperfection in the contrary respect. They prove that water conducts electricity according to its quantity, and that a small quantity of water makes a very great resistance to the passage of the electric fluid.

HE made tubes, full of water, part of the electric circuit, and observed, that when they were very small, they would not transmit a shock, but that the shock increased as wider tubes were used †.

BUT what astonishes us most in Signior Beccaria's experiments with water, is his making the electric spark visible in it, notwithstanding its being a real conductor of electricity. Nothing, however, can prove more clearly how imperfect a conductor it is.

HE inserted wires, so as nearly to meet, in small tubes filled with water; and, discharging shocks through them, the electric spark was visible between their points, as if no water had been in the place. The tubes were generally broken to pieces, and the fragments driven to a considerable distance. This was evidently occasioned by the repulsion of the water, and its incompressibility, it not

* Elettricismo artificiale e naturale, p. 81.
† Ibid. p. 113.

being

being able to give way far enough within itſelf, and the force with which it was repelled being very great *.

The force with which ſmall quantities of water are thus repelled by the electric fluid, he ſays, is prodigious. By means of a charge of four hundred ſquare inches, he broke a glaſs tube two lines thick, when the pieces were driven to the diſtance of twenty feet. Nay he ſometimes broke tubes eight or ten lines thick, and the fragments were driven to greater diſtances in proportion †.

He found the effect of the electric ſpark upon water greater than the effect of a ſpark of common fire on gunpowder; and ſays he does not doubt, but that, if a method could be found of managing them equally well, a cannon charged with water would be more dreadful than one charged with gunpowder. He actually charged a glaſs tube with water, and put a ſmall ball into it, when it was diſcharged with great force, ſo as to bury itſelf in ſome clay which he placed to receive it ‡.

This reſiſtance which ſmall quantities of water make to the electric matter, he imagined, was greater than the reſiſtance made to it by air §. And yet he thought it was

* Elettriciſmo artificiale e naturale, p. 114.

† Lettre dell' elettriciſmo, p. 74.

‡ Ibid. p. 75, 76. Mr. Lullin ſays, he produced much greater effects than theſe, by making the electric ſpark viſible in *oil* inſtead of water. Oil being a much worſe conductor, the ſpark in it would be larger. Diſſertatio Phyſica, p. 26.

§ Elettriciſmo artificiale, &c. p. 115.

poſſible,

possible, that, in this case, the electric matter might not act upon the water immediately, but upon the fixed air that was in it. For when the tubes were not broken, he observed that a great number of air bubbles were let loose, through the whole mass of the water, rose to the top, and mixed with the common atmosphere *.

He also imagined that the electric fluid acted upon the fixed air in all bodies, though no experiment could make it sensible †.

On the contrary, he supposed that the action of the electric matter tended to fix elastic air, by exciting a sulphureous matter, which Dr. Hales shows to have that property ‡. But the experiment above-mentioned, of the electric spark taken in a closed tube, doth not favour this supposition.

When a small drop of water was put between the points of two wires, and a large shock passed through them, the water was equally dispersed on the inside of a glass sphere, in which they were all inclosed. In the same manner, he conjectures, that the action of the electric matter promotes the evaporation of water §.

Discharging a shock through a quantity of water, poured on a flat surface, where some parts of the circuit were purposely left almost dry; those parts became quite dry sooner than they would have been, if no shock had passed through them ‖.

* Elettricismo artificiale, &c. p. 116. † Ibid. p. 83. ‡ Ibid. § Ibid. p. 117. ‖ Ibid. p. 121.

Upon

Upon this principle he accounts for the ſuppoſed burſting of the blood veſſels in ſmall birds killed by the electric ſhock*, And when a muſcle contracts by the ſhock, he ſuppoſes it is owing to the dilatation of the fluids their fibres contain, as the electric matter paſſes through them.

So imperfect a conductor of electricity is mere water, that, he thought, a green leaf conducted a ſhock better than an equal thickneſs of water †. If this be true, and vegetable fluids conduct electricity better than water, it will confirm a conjecture which Dr. Franklin told me he had drawn from ſome experiments that he had not properly purſued, viz. that animal fluids conducted electricity better than water. He tried milk many years ago; and Mr. Kinnerſley, and others in America, have ſince tried blood and urine, and alſo the ſinews of animals newly killed; and they were all found to be exceedingly good conductors, remarkably better than water.

Signior Beccaria alſo found, that even *metal* was not a perfect conductor of electricity, but made ſome reſiſtance to the paſſage of the electric fluid. This he aſcertained, by meaſuring the time that it was retarded, in its paſſing through long and ſmall wires, notwithſtanding the experiments which had been made before, that ſeemed to prove the contrary.

* Elettriciſmo artificiale, &c. p. 128. † Ibid. p. 135.

He

He suspended a wire of five hundred Paris feet, in a large building, and, by means of a pendulum which vibrated half seconds, observed, that light bodies placed under a ball of gilt paper, at one end, did not move, till, at least, one vibration of this pendulum, after he had applied the wire of a charged phial to the other.

Trying the same with a hempen cord, he could count six, or more vibrations before they would stir; but when he had wetted the cord, they were moved after two or three vibrations *. He does not, however, absolutely say that, the electric fluid must have taken up all this time in its progress, as it might require a certain quantity of the fluid, before it could raise the light bodies. But he did imagine, that it moved with more velocity, in proportion as the bodies into which it passed had more or less of the fluid before †. And he was confirmed in this opinion by several phenomena of the atmosphere, which will be related in their proper place, particularly by seeing, very evidently, the progress of a quantity of electric matter in the air, as it advanced to strike his kite.

To these experiments of Signior Beccaria on the conducting powers of air and water, I shall subjoin another curious set of the same author, showing the manner in which the smoke of rosin and of colophonia is affected by the approach of an electrified

* Elettricismo artificiale, &c. p. 51. † Ibid.

body,

body, as they have a very near affinity to this ſubject.

Repeating Dr. Franklin's experiments to make electric atmoſpheres viſible with the fume of colophonia, which he preferred, for this purpoſe, to roſin; he obſerved ſeveral curious circumſtances, which had eſcaped the notice of that ingenious philoſopher.

He heated the colophonia on a coal, which he held in a ſpoon under an electrified cube of metal; and obſerved, that when part of the ſmoke aſcended to the cube, another part covered the handle of the ſpoon, and ſpread to his hand *.

The ſmoke lay higher on the flat parts of the cube than on the edges, and corners.

If a ſpark was taken from the conductor, the ſmoke was thrown into an agitation, but preſently reſumed its former ſituation.

The cube with its atmoſphere gave larger, and longer ſparks, than a cube not ſurrounded with one.

A larger ſpark might be taken from it by the ſpoon, than by any other body.

Having inſulated the ſpoon, he obſerved, that hardly any of the ſmoke went to the cube; and that what happened to go near it was not affected by it, any more than it would have been by any other body. He put his finger to the ſpoon, and the former phenomena returned. Taking it off again,

* Elettriciſmo artificiale, p. 72.

the

the ſmoke that had ſettled on the cube ſoon diſperſed *.

UNDER this head of the electricity of various ſubſtances, it will not be improper to mention an experiment made by Mr. Henry Eeles of Liſmore in Ireland, which, he thought, proved that ſteam, and exhalations of all kinds, are electrical. The paper containing this account was read at the Royal Society, April the 23d, 1755.

HE electrified a piece of down, ſuſpended on the middle of a long ſilk ſtring, and made ſteam and ſmoke of ſeveral kinds paſs under it, and through it; and obſerved, that its electricity was not in the leaſt diminiſhed, as he thought it would have been, if the vapour had been non-electric, and conſequently had taken away with it part of the electric matter with which the down was loaded. He obſerved that the effect was the ſame, whether the down was electrified with glaſs or wax, which he thought was not eaſy to be accounted for †.

To this experiment Dr. Darwin of Litchfield, in a letter addreſſed to the Royal Society, and read May the 5th, 1757, anſwers; that many electrified bodies, and particularly all light, dry, animal, and vegetable ſubſtances, will not eaſily part with their electricity, though they be touched, for a conſiderable time, with conductors. He touched

* Elettriciſmo artificiale, p. 73, 74.
† Phil. Tranſ. Vol. xlix. pt. i. p. 153.

a feather,

a feather, electrified like that of Mr. Eeles, nine times with his finger, and still found it electrified. A cork ball was touched seven times in ten seconds before it was exhausted*.

Mr. Kinnersley of Philadelphia, in a letter dated March 1761, informs his friend and correspondent Dr. Franklin, then in England, that he could not electrify any thing by means of *steam* from electrified boiling water; from whence he concluded, that, contrary to what had been before supposed by himself and his friend, steam was so far from rising electrified, that it left its share of common electricity behind †.

To try the effects of electricity upon air, Mr. Kinnersley contrived an excellent instrument, which he calls *an electrical air thermometer*. It consisted of a glass tube, about eleven inches long, and one inch in diameter, made air tight, closed with brass caps at each end, and a small tube, open at both ends, let down through the upper plate, into some water at the bottom of the wider tube. Within this vessel he placed two wires, one descending from the brass cap at the upper end, and the other ascending from the brass cap at the lower end; through which he could discharge a jar, or transmit a spark, &c. and at the same time see the expansion of the air in the vessel, by the rise of the water, in the small tube. With this instrument he made the following experiments, related in a let-

* Phil. Tranf. Vol. l. pt. i. p. 252.
† Ibid. Vol liii. pt. i. p. 84.

ter to Dr. Franklin, dated March the 12th, 1761.

He ſet the thermometer on an electric ſtand, with the chain fixed to the prime conductor, and kept it well electrified a conſiderable time; but this produced no conſiderable effect: from whence he inferred, that the electric fire, when in a ſtate of reſt, had no more heat than the air, and other matter wherein it reſides.

When the two wires within the veſſel were in contact, a large charge of electricity, from above thirty ſquare feet of coated glaſs, produced no rarefaction in the air; which ſhowed, that the wires were not heated by the fire paſſing through them.

When the wires were about two inches aſunder, the charge of a three pint bottle, darting from one to the other, rarefied the air very evidently; which ſhewed, that the electric fire produced heat in itſelf, as Mr. Kinnerſley ſays, as well as in the air, by its rapid motion.

The charge of a jar which contained about five gallons and a half, darting from wire to wire, would cauſe a prodigious expanſion in the air; and the charge of his battery of thirty ſquare feet of coated glaſs would raiſe the water in the ſmall tube quite to the top. Upon the coaleſcing of the air, the column of water, by its gravity, inſtantly ſubſided, till it was in equilibrio with the rarified air. It then gradually deſcended, as the air cooled, and ſettled where it ſtood before. By carefully

fully obſerving at what height the deſcending water firſt ſtopped, the degree of rarefaction, he ſays, might be diſcovered, which, in great exploſions, was very conſiderable.

It is obvious to remark, that the firſt ſudden riſe of the water of Mr. Kinnerſley's thermometer, upon an exploſion being made in the veſſel which contained it, is not to be aſcribed to the rarefaction of the air by heat, but to the quantity of air actually diſplaced by the electrical flaſh. It is only when that firſt ſudden riſe is ſubſided, as Mr. Kinnerſley himſelf obſerves, that the degree of its rarefaction by the heat can be eſtimated, viz. by the height at which the water then ſtands above the common level.

Dr. Franlkin had ſaid, that *ice* failed to conduct a ſhock of electricity, and Mr. Bergman, in a letter to Mr. Wilſon, read at the Royal Society November the 20th, 1760, ſhows (what Signior Beccaria had done before) that a ſmall quantity of water failed as much as the ice had done with Dr. Franklin, who ſeems to have made uſe of an icicle which, Mr. Bergman thought, was not large enough for the purpoſe. From hence he ſuſpected, that large quantities of ice would tranſmit a ſhock of electricity as perfectly as a large quantity of water *.

However, he ſeems, afterwards, to have changed his ſentiments with reſpect to ice: for, in a ſubſequent paper, read at the Royal

* Phil. Tranſ. Vol. li. pt. ii. p. 908.

Society March the 18th, 1762, when he had remarked that ſnow would not conduct the electric ſhock, he ſays, he believes, if he could procure plates of ice of a proper thickneſs, he could charge them in the ſame manner as glaſs *.

JOHANNES FRANCISCUS CIGNA was ſo fully perſuaded of the non-conducting power of ice, that he made uſe of it in an experiment, deſigned to aſcertain whether electric ſubſtances did, according to Dr. Franklin's hypotheſis, contain more of the electric matter than other bodies. He incloſed a quantity of ice in a glaſs veſſel, and when he thought he had converted it from an electric to a non-electric by melting; he tried whether it was electrified; but, though he found no appearance of its having acquired any more of the fluid than it ought to have in its new ſtate, he does not ſeem to have given up his opinion †.

IN the laſt part of this work the reader will find ſome experiments, which, it is imagined, will aſcertain the claſs of bodies in which ice ought to be ranked, by proving its conducting power to be, at leaſt, nearly equal to that of water.

* Phil. Tranſ. Vol lii. pt. ii. p. 485.
† Memoirs of the Academy at Turin, for the year 1765, p. 47.

SECTION

SECTION III.

MR. CANTON's EXPERIMENTS AND DISCOVERIES RELATING TO THE SURFACES OF ELECTRIC BODIES, AND OTHERS MADE IN PURSUANCE OF THEM, OR RELATING TO THE SAME SUBJECT; ALL TENDING TO ASCERTAIN THE DISTINCTION BETWEEN THE TWO ELECTRICITIES.

TILL this laſt period of the hiſtory, the ſame electricity had always been produced by the ſame electric. The friction of glaſs had always produced a poſitive, and the friction of ſealing-wax, &c. had always produced a negative electricity. Theſe were thought to be eſſential, and unchangeable properties of thoſe ſubſtances; and hence the one was by many called the vitreous, and the other the reſinous electricity; and to electrify negatively, that is produce a reſinous electricity, by means of glaſs; or to electrify poſitively, that is, produce a vitreous electricity, by means of ſealing-wax, &c. would have been thought as great a paradox, as to electrify at all by the friction of braſs or iron. For though it was not known why the electric matter ſhould flow from the rubber to the excited glaſs, or to the rubber from excited ſealing-wax, the fact had been invariable; and nothing is even mentioned to have happened, in the courſe of any experi-

 ments,

ments, that could lead a person to suspect the possibility of the contrary.

WHAT then must have been the surprise of electricians, to find that these different powers of glass and sulphur were so far from being invariable, that they were even interchangeable; and that the same glass tube could be made to assume the powers of both! And what must have been their satisfaction to find the circumstance on which the convertibility of those opposite powers depended, completely ascertained. This surprise and pleasure was given them by Mr. Canton, who showed that it depended only on the rubber, and the surface of the glass, whether it electrified positively or negatively.

IN what manner, by what train of thought, or by what accident he was led to this discovery, this excellent philosopher has not been pleased to inform us; but it is certainly a discovery which, in an eminent manner, distinguishes this period of my history. It throws great light upon the doctrine of positive and negative electricity, and led the way to other discoveries which throw still more light upon it.

THIS subject of the two electricities seems to have engaged the attention of electricians in a more particular manner, in the whole course of this period, and ever since the discovery of Dr. Franklin, that the electricity of the two surfaces of charged glass are always contrary to one another. Accordingly, the reader will find several sections in this period

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of the hiſtory relating to it; but he will find that though much has been done, much yet remains to be done; and that we are ſtill far from thoroughly underſtanding the nature of the two electricities, with their dependence upon and relation to one another.

PREVIOUS to the communication of the diſcovery itſelf, Mr. Canton obſerves, that ſealing-wax might have poſitive electricity ſuperinduced upon it. He excited a ſtick of ſealing-wax about two feet and a half in length, and an inch in diameter; and, holding it by the middle, he drew an excited glaſs tube ſeveral times over one part of it, without touching the other. The conſequence was, that that half which had been expoſed to the action of the excited glaſs was poſitive, and the other half negative: for the former half deſtroyed the repelling power of balls electrified by glaſs, while the other half increaſed it *.

THE experiments, which prove that the appearances of poſitive and negative electricity depend upon the ſurface of the electrics, and that of the rubber, were made in the latter end of December 1753.

HAVING rubbed a glaſs tube with a piece of thin ſheet lead, and flour of emery mixed with water, till its tranſparency was intirely deſtroyed, he excited it (when it was made perfectly clean and dry) with new flannel, and found it act in all reſpects like excited

* Phil. Tranſ. Vol. xlviii. pt. i. p. 356.

sulphur or sealing-wax. The electric fire seemed to issue from the knuckle, or end of the finger, and to spread itself on the surface of the tube, in a very beautiful manner.

IF this rough or unpolished tube was excited by a piece of dry oiled silk, especially when rubbed over with a little chalk or whiting, it would act like a glass tube with its natural polish. In this case the electric fire appeared only at the knuckle, or the end of the finger, where it seemed to be very much condensed, before it entered.

BUT if the rough tube was greased all over with tallow from a candle, and as much as possible of it wiped off with a napkin, then the oiled silk would receive a kind of polish by rubbing it; and, after a few strokes, would make the tube act in the same manner as when excited at first by flannel.

THE oiled silk, when covered with chalk or whiting, would make the greased rough tube act again like a polished one; but if the friction was continued till the rubber became smooth, the electric power would be changed to that of sulphur, sealing-wax, &c.

THUS, says he, may the positive and negative powers of electricity be produced at pleasure, by altering the surfaces of the tube and rubber, according as the one or the other is most affected by the friction between them. For if the polish be taken off one half of a tube, the different powers may be excited with the same rubber at a single stroke; and, he adds, the rubber is found to move much

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easier over the rough, than over the polished part of it.

That polished glass electrified positively, and rough glass rubbed with flannel negatively, seemed plain from the appearance of the light between the knuckle, or end of the finger, and the respective tubes. But this, Mr. Canton thought, was farther confirmed by observing, that a polished glass tube, when excited by smooth oiled silk, if the hand was kept three inches, at least, from the top of the rubber, would, at every stroke, appear to throw out a great number of diverging pencils of electric fire; but that none were ever seen to accompany the rubbing of sulphur, sealing-wax, &c. nor was he ever able to make any sensible alteration in the air of a room merely by the friction of those bodies; whereas the glass tube, when excited so as to emit pencils, would, in a few minutes, electrify the air, to such a degree, that, after the tube was carried away, a pair of balls, about the size of the smallest peas, turned out of cork, or the pith of elder, and hung to a wire by linen threads of six inches long, would repel each other to the distance of an inch and an half, when held at arm's length in the middle of the room *.

After these experiments of Mr. Canton, Mr. Wilson made several, which throw a little more light upon this curious subject; but it is difficult to draw any general conclu-

* Phil. Transf. Vol. xlviii. pt. ii. p. 782.

sion from them, and his own is not sufficiently determinate. It is, that two electrics being rubbed together, the body whose substance is hardest, and electric power strongest, will always be *plus*, and the softest and weakest *minus* *. Rubbing the tourmalin and amber together, he produced a *plus* electricity on both sides of the stone, and a *minus* on the amber; but rubbing the tourmalin and diamond together, both sides of the tourmalin were electrified *minus*, and the diamond *plus*.

These experiments, which, he thought, proved this proposition, encouraged him to try what would be the effect of rubbing or forcing air against different electrics, and the effects were very considerable. In these experiments he only made use of a common pair of bellows, and his first experiment was upon the tourmalin. This substance he brought near the end of the pipe, and found, that after it had received about twenty blasts, it was electrified *plus* on both sides. Air, therefore, seemed to be less electric than the tourmalin.

Into the place of the tourmalin, he brought a pane of glass, and blew against it the same number of times as in the former experiment; and when he had examined both sides, he found that they were electrified *plus* also, but less than the tourmalin.

Amber, treated in the same manner, was electrified less than the glass.

* Phil. Trans. Vol. li. pt. i. p. 331.

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He next had recourse to a smith's bellows. The difference which these occasioned was only a much stronger electricity in the tourmalin. Amber was still weaker than the glass; and the glass weaker than the tourmalin.

Having in view the medium (which, I have observed, he laid great stress upon, as constituting the difference between electrics and non-electrics) he considered that heat would rarify it on the surfaces of the particles of air; by which means, air, having its resistance lessened, would more readily part with the electric fluid, and, of consequence, electrify more powerfully.

The pipe of the bellows being made red hot, he blew against the tourmalin, twelve times only, which was eight times less than in the former experiment with cold air. In this experiment the tourmalin was electrified *plus* on both sides, but to a considerable degree more than was done in the former experiments. The hot air had the same effect upon glass, but electrified it less than the tourmalin; and amber, though, like the other bodies, it received an increase of power by the same treatment, was electrified the least of all.

From the air electrifying more powerfully when it was hot than when it was cold, and the tourmalin being electrified more than glass, and glass more than amber, as appeared by the last experiments, we seem, says Mr. Wilson, to have obtained a proof, that the

the whole atmosphere is constantly promoting a flow of the electric fluid, by the alternate changes of heat and cold; and farther, that air is not only less electric than the tourmalin, but less than glass, or even amber *.

IN another paper, read at the Royal Society November the 13th, 1760, Mr. Wilson recites some curious experiments, which, he says, shew that a *plus* electricity may be produced by means of a *minus* electricity.

HAVING electrified the inside of a large Leyden bottle *plus*, by means of a conducting wire from an excited glass globe; he set it on a stand of prepared wood, and took away the conducting wire, after which the mouth of the bottle was closed with a stopple of glass. Then the pointed end of an ivory conductor was brought opposite to the middle of the bottle, and about two inches from it. Upon doing this, the balls were electrified *minus*; and the more so as the ivory was moved nearer the bottle, in an horizontal direction.

BUT, on removing the ivory to a greater distance, the *minus* electricity decreased; and, at a certain distance, there was not any sign of it remaining; but when the distance was increased to about eighteen inches from the bottle, a *plus* electricity appeared, which continued even after the ivory was removed entirely away †.

WITH a cylinder of baked wood he electrified the balls hanging to the ivory *minus*, at

* Phil. Tranf. Vol. li. pt. i. p. 332, &c.
† Ibid. pt. ii. p. 899, &c.

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the diſtance of four feet or more, by holding the cylinder over the middle of the ivory, and continuing it there; and, on moving it nearer, they were more ſtrongly electrified *minus*; but the ſame cylinder, on removing it back again to the diſtance of two or three feet, or more, electrified the balls *plus*.

When another conductor of metal, without edges or points, was uſed, inſtead of the ivory, and without any thing hanging from it, the ſame cylinder held over the metal (as was done in the laſt experiment over the ivory, at the diſtance of two feet) produced a *plus* electricity; and this was rendered weaker as the cylinder was moved nearer; but by leſſening the diſtance to about one foot, the *minus* electricity took place. In theſe caſes Mr. Wilſon thought, that the *plus* appearance aroſe from the earth, air, or other neighbouring bodies.

When the preceding experiments were firſt made, he was a little embaraſſed, by the uncertain appearances of a *plus* electricity at one time, and a *minus* at another, in the ſame experiment; but, by repeated trials and obſervations, he found, that a *plus* or *minus* electricity may be produced at pleaſure, by carefully attending to the three following circumſtances; viz. the form of the bodies, their ſudden or gradual removal, and the degrees of electrifying.

Mr. Wilson, after this, proceeds to mention ſome other circumſtances of a very nice nature, where, the ſlighteſt and almoſt imperceptible

perceptible differences in the poſition or in the courſe of the friction of two bodies produce, in either of them, the *plus* electricity at one time, and the *minus* at another. Such, ſays he, are the effects of this ſubtle and active fluid, when the experiments are carefully made; and therefore they require the moſt ſcrupulous attention to trace out the cauſes which occaſion them.

Sealing-wax and ſilver were the bodies uſed in the two firſt experiments, but many other ſubſtances ſeemed to perform as well. The ſealing-wax was clean, and undiſturbed by any friction whatever, but that of the air ſurrounding it, and had been ſo for ſome hours. The ſilver was fixed to a piece of prepared wood, which was alſo preſerved from friction for the ſame length of time. Then, taking one of thoſe ſubſtances in each hand, the ſilver being at the end of the wood the fartheſt from the hand, he laid the ſmootheſt part of the ſilver upon the ſealing-wax, and moved it along the ſurface gently, once only, and with a very ſlight preſſure, after which the ſilver was electrified *plus*, and the wax *minus*.

On repeating the experiment with equal care, and in the ſame manner, except that the ſmooth ſide of the ſilver was a little inclined, ſo that the edge of it preſſed againſt the wax; the ſilver, after moving it as before, was electrified *minus*, and the wax *plus*, contrary to what was obſerved in the laſt experiment.

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THESE opposite effects, occasioned by the different applications of the *flatted part* or *edge* of the silver, seemed to arise from an alteration made in the surface of the wax, by destroying the polish in one case, and not in the other; and in this respect resembled the polished and rough glass mentioned before.

UPON making use of prepared wood instead of wax, and employing different degrees of pressure in the friction, with the same edge of the silver, he produced the like appearances; the least pressure causing a *plus*, and the greatest pressure a *minus* appearance in the silver.

A FLAT piece of steel well polished, and the edges rounded off, afforded the same appearances, by only applying the flat surface to the wood, but it required more pressing to produce the *minus* effect in this case than it did in the former, where the edge was concerned.

WHETHER the reason offered above for explaining these last curious appearances be true or not, Mr. Wilson did not venture to affirm, for want of farther experiments; but thus much he thought might be safely advanced, that we have learned to produce at pleasure a *plus* or *minus* electricity from the same bodies, by attending to the manner of their application and friction *.

MR. BERGMAN, in a letter to Mr. Wilson, read at the Royal Society February the 23d,

* Phil. Trans. Vol. li. pt. ii. p. 899, &c.

1764,

1764, gives an account of some curious experiments of his, which, in conjunction with those of Mr. Canton above mentioned, concerning surfaces, may throw considerable light upon the doctrine of positive and negative electricity.

The experiments were made with two ribbons of silk, one of which was extended in a frame, while Mr. Bergman held the other in his hand. He observed, that if the two ribbons were the same with respect to texture, colour, superficies, and in every thing else, as far as could be judged; and if he drew the whole length of the ribbon which he held in his hand over one part of that which was extended in the frame, that in his hand contracted the positive electricity, and that in the frame a negative. If he drew one part of that which he held in his hand over the whole length of the other, the effects were reversed.

If the ribbon in his hand was of a different colour from that in the frame (provided it was not black) the event was the same.

If the ribbon in his hand was black, it was always negative, which ever way it was rubbed, except that in the frame was black too; for then, if the whole length of it was rubbed, it was electrified positively.

In endeavouring to account for these effects, he observes, that the ribbon which was most rubbed was made *smoother*, and *warmer* than the other; and was of opinion, that though smoothness did dispose bodies to be excited positively,

positively, yet that other circumstances were also to be taken into consideration; having found that when he held in his hand a ribbon, which, by much friction, was made very smooth, and drew it over one part of another ribbon, which was rough, and had never been used before, that the rough ribbon was, nevertheless, positive. From this experiment he concluded, that this effect was, in some measure, owing to the colour; and, in pursuing this thought farther, he was led to the following experiments.

If the ribbon in his hand was well warmed, though it was drawn over one part of that in the frame, it became electrified negatively, and that in the frame positively. He made these experiments with the same success upon ribbons of silk of various colours, blue, green, red, white, &c.

If the ribbon in the frame was black, it never contracted a positive electricity, though that in his hand had been much heated, except this were black too. From these experiments, he thought he might safely conclude, that heat did dispose some substances, at least, to a negative state; and he thought that the want of attention to this circumstance might have occasioned mistakes in the event of some experiments, especially those concerning island crystal.

From the whole he concludes, that there is a certain fixed order with respect to negative and positive electricity, in which all bodies may be placed, while other circumstances

ſtances remain the ſame. Let A, B, C, D, E, be certain ſubſtances, each of which, when rubbed with one which is antecedent to it, is negative, but with a ſubſequent poſitive. In this caſe, the leſs diſtance there is between the bodies that are rubbed, the weaker, *cæt. par.* will be the electricity; wherefore it will be ſtronger between A and E, than it will be between A and B. Heat, he ſays, diſpoſes bodies to a negative electricity, but if the diſtance above-mentioned be conſiderable, it may not be able to *overcome*, though it may *weaken* that electricity, as is evident from the ribbon of black ſilk. When a glaſs globe grows warm in whirling, we are ſenſible that its electric power is diminiſhed. Is it not owing, ſays he, to this circumſtance, that by heat it is more diſpoſed to negative electricity, by which means the diſtance above-mentioned between the glaſs and the rubber is leſſened * ?

UPON the ſubject of this ſection, I muſt introduce to the acquaintance of my reader two eminent electricians whoſe diſcoveries will give him the greateſt ſatisfaction; I mean Mr. WILCKE, and Mr. ÆPINUS, the former of Roſtock in Lower Saxony, and the latter of Peterſburgh: a circumſtance which gives me an occaſion of congratulating all the lovers of the ſciences, and particularly of electricity, on the extenſive ſpread of their ſtudies. What joy would it have given Mr.

* Phil. Tranſ. Vol. liv. p. 86.

Haukſbee,

Haukſbee, or Mr. Grey, to have foreſeen that two ſuch admirable treatiſes on the ſubject of electricity, as thoſe of the perſons abovementioned, would come from countries ſo remote from the place of its riſe!

Mr. Wilcke relates many curious experiments concerning the generation of what he calls *ſpontaneous electricity*, produced by the liquefaction of electric ſubſtances, which, compared with thoſe of Mr. Canton, throw great light upon the doctrine of poſitive and negative electricity.

He melted ſulphur in an earthen veſſel, which he placed upon conductors; then, letting them cool, he took out the ſulphur, and found it ſtrongly electrical; but it was not ſo when it had ſtood to cool upon electric ſubſtances.

He melted ſulphur in glaſs veſſels, whereby they both acquired a ſtrong electricity in the circumſtances above mentioned, whether they were placed upon electrics or not; but a ſtronger in the former caſe than in the latter; and they acquired a ſtronger virtue ſtill, if the glaſs veſſel into which they were poured was coated with metal. In theſe caſes, the glaſs was always poſitive, and the ſulphur negative. It was particularly remarkable, that the ſulphur acquired no electricity till it began to cool and contract, and was the ſtrongeſt when in the ſtate of greateſt contraction; whereas the electricity of the glaſs was, at the ſame time, the weakeſt; and was the ſtrongeſt of all when the ſulphur was ſhaken

out, before it began to contract, and acquired any negative electricity.

PURSUING these experiments, he found that melted sealing-wax, poured into glass, acquired a negative electricity, but poured into sulphur it acquired a positive electricity, and left the sulphur negative. Sulphur poured into baked wood became negative. Sealing-wax also poured into wood was negative, and the wood consequently positive; but sulphur poured into sulphur, or into rough glass, acquired no electricity at all *.

EXPERIMENTS similar to these were also made by Mr. Æpinus. He poured melted sulphur into metal cups, and observed that when the sulphur was cold, the cup and the sulphur together showed no signs of electricity, but showed very strong signs of it the moment they were separated. The electricity always disappeared when the sulphur was replaced in the cup, and revived upon being taken out again. The cup had acquired a negative, and the sulphur a positive electricity; but if the electricity of either of them had been taken off while they were separate, they would both, when united, show signs of that electricity which had not been taken off. This electricity, he observes, was only on the surface of the sulphur †.

MR. WILCKE has, likewise, recited several curious experiments, which he made on the friction of various substances, which like-

* Wilcke, p. 44, &c. † Æpini Tentamen, p. 66. 70.

wise

wife throw confiderable light on the fame fubject.

SULPHUR and glafs rubbed together produced a ftrong electricity, pofitive in the glafs, and negative in the fulphur.

SULPHUR and fealing-wax being rubbed together, the wax became pofitive, and the fulphur negative.

WOOD rubbed with cloth was always negative.

WOOD rubbed againft fmooth glafs became negative, but againft rough glafs pofitive.

SULPHUR rubbed againft metals was always pofitive, and this was the only cafe in which it was fo; but being rubbed againft lead it became negative, and the metal pofitive; lead appearing, thereby, to be not fo good a conductor as the other metals.

AFTER thefe experiments, Mr. Wilcke gives the following catalogue of the principal fubftances with which electrical experiments are made, in the order in which they are difpofed to acquire pofitive or negative electricity; any of the fubftances becoming pofitively electrical when rubbed with any that follow it in the lift, and negative when rubbed with any that precede it.

Smooth glafs.	White wax.
Woollen cloth.	Rough glafs.
Quills.	Lead.
Wood.	Sulphur.
Paper.	Other metals *.
Sealing-wax.	

* Wilcke, p. 54, &c.

In all experiments made to determine the order of these substances, Mr. Wilcke says, that great care is necessary, to distinguish original electricity from that which is communicated, or the consequence of friction *.

Mr. Wilcke says that smooth glass is in all cases positive, and thence infers that it attracts the electric fluid the most of all known substances; but Mr. Canton tells me he has found, that the smoothest glass will acquire a negative electricity by being drawn over the back of a cat.

Of the same nature with these experiments of Mr. Wilcke are the following of Æpinus. He pressed close together two pieces of looking-glass, each containing some square inches; and observed, that when they were separated, and not suffered to communicate with any conductor, they each acquired a strong electricity, the one positive, and the other negative. When they were put together again, the electricity of both disappeared, but not if either of them had been deprived of their electricity when they were asunder; for in that case, the two when united, had the electricity of the other. The same experiment, he says, may be made with glass and sulphur, or with any other electrics, or with any electric and a piece of metal †.

* Wilcke, p. 69. † Æpini Tentamen, p. 65.

SECTION

SECTION IV.

Mr. DELAVAL's experiments relating to the two electricities, and his controversy with Mr. CANTON upon that subject.

MR. CANTON, in the courſe of experiments related in the preceding ſection, clearly proved, that the production of either of the two electricities depends intirely upon the ſurface of the excited electric with reſpect to the rubber, and ſhowed, that the very ſame glaſs tube would produce either of them at pleaſure; yet, notwithſtanding this demonſtration, Mr. Delaval, ſeveral years afterwards, propoſed another theory of the two electricities, which ſeems to be more ingenious than ſolid; as it goes upon the old ſuppoſition of the different powers depending intirely upon the different ſubſtances themſelves. The account of this theory was read at the Royal Society, March the 22d, 1759. It neceſſarily occaſioned ſome controverſy with Mr. Canton, in the courſe of which ſome new experiments were made, and ſome new facts diſcovered; on account of which I ſhall, with the utmoſt impartiality, report all that was advanced on both ſides.

Mr. Delaval obſerved, that there are two of the pure chymical principles of bodies, viz. *earth* and *ſulphur*, which are each poſ-

ſeſſed of a different kind of electricity; one of which we might call a *plus* electricity, the other a *minus*; and thought that it might be expected, that, in a body compounded of both, the oppoſite powers of thoſe ingredients would counterbalance, and deſtroy the effect of each other; and therefore, that bodies in which the negative and poſitive powers were equal, would be neutral, or non-electrics. Such a ſubſtance he took metal to be, conſiſting of calx and ſulphur; metals not being calcinable without a degree of heat ſufficient to diſſipate all their ſulphur; as is evident from their not being reducible again to their metallic form, without the admixture of ſome unctuous matter. The ſame diſſipation of ſulphur, he ſays, muſt take place in animal and vegetable ſubſtances, before they become white aſhes. Tranſparent ſtones he conſidered as little more than pure earth, free from the leaſt mixture of oil; judging of others by the chymical reſolution of cryſtal.

To confirm this theory, Mr. Delaval made experiments with dry powders of calcined metals, viz. ceruſs, lead aſhes, minium, calx of antimony, &c, incloſing them in long glaſs tubes, and endeavouring to tranſmit the electric virtue through them, and always finding it impoſſible. Animal and vegetable ſubſtances, when reduced to aſhes, were alike impermeable to electricity, as alſo the ruſt of metals.

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He was firſt led to theſe experiments, and to this hypotheſis, by finding that dry mould would not conduct electricity. This he alſo tried with dry Portland ſtone, ſome of which he had cut into plates nearly as thin as window glaſs. Theſe he heated to a proper degree, and coated them on both ſides with metal, in order to make the Leyden experiment. When the ſtone was hot enough to ſinge paper, it conducted as perfectly as when cold; but on cooling a little, it began not to conduct, and afforded ſmall ſhocks; which gradually increaſed in ſtrength for about ten minutes, at which time it was about its moſt perfect ſtate, and remained ſo near a quarter of an hour. After that time, the ſhocks gradually decreaſed, as the ſtone grew cooler; till, at laſt, they ceaſed, and the ſtone returned to its conducting ſtate again, but this ſtate appeared before the ſtone was quite cold.

Experiments of this kind ſucceeded with all bodies abounding with calx, or earth, as ſtones, earth, dry clay, wood when rotten, or burned in the fire till the ſurface becomes black. Among other ſubſtances he tried a common tobacco-pipe, part of which, near the middle, he heated to a proper degree, and then applied one end of it to an electrical bar, while the other was held in the hand; and he obſerved, that the electric fluid paſſed no farther along the pipe than to the heated part *.

* Phil. Tranſ. Vol. li. pt. i. p. 83.

FROM theſe experiments Mr. Delaval inferred, that ſtones and other earthy ſubſtances were convertible, by ſeveral methods, and particularly by different degrees of heat, from non-electrics to electrics. But finding, afterwards, that it was the opinion of ſome perſons (Mr. Canton was the perſon chiefly hinted at) that this change did not immediately, but only conſequentially depend on heat, by evaporating the moiſture, which would return again when the ſubſtance cooled; he obſerves, in a paper read at the Royal Society, December the 17th, 1761, that the tobacco-pipe loſt its electricity before it was cold, and therefore before it could have imbibed moiſture ſufficient to deſtroy its electricity; and beſides, that the ſubſtance employed in the experiment was not of that kind of bodies which is apt ſuddenly to draw moiſture from the air.

To account for Mr. Delaval's experiments, Mr. Canton ſuppoſes, in a paper read to the Royal Society, February 4th, 1762, that ſtone, tobacco-pipe, wood, &c. will conduct when cold by the moiſture they contain in that ſtate; that when their moiſture is evaporated by heat they become non-conductors; and that when they are made very hot, the hot air at, or near their ſurfaces will conduct, and the bodies will appear to be conductors again. Hot air, he ſays, may eaſily be proved to be a conductor of electricity, by bringing a red hot-iron poker, but for a moment, within three or four inches of a ſmall electri-

fied

fied body; when it would be perceived, that its electric power would be almoft, if not intirely deftroyed; and by bringing excited amber within an inch of the flame of a candle, when it would lofe its electricity before it had acquired any fenfible degree of heat.

To confirm this, he mentions his having obferved, that the tourmalin, Brafil topaz, and Brafil emerald, would give much ftronger figns of electricity when cooling, after they had been held about a minute within two inches of an almoft furrounding fire, where the air is a conductor, then they ever will after heating them in boiling water. He adds, that if both fides of thofe ftones be equally heated, in a lefs degree than will make the furrounding air a conductor, the electricity of each fide, whether *plus* or *minus*, would continue fo all the time the ftone was both heating and cooling, but would increafe while it was heating, and decreafe while it was cooling; whereas, if the heat was fufficient to make the furrounding air conduct the electric fluid from the pofitive fide of the ftone to the negative fide of it, while it was heating, the electricity of each fide would increafe while the ftone was cooling, and be contrary to what it was while the ftone was heating.

As to the tobacco-pipe, Mr. Canton fays, that it not only attracts the moifture of the air, but abforbs it. Hence a tobacco-pipe, after it begins to cool, will become a conductor again fooner than wood. And that it imbibes moifture fafter than wood, he fays, is

evident,

evident, becauſe when wetted, it will not continue wet ſo long as wood, imbibing the moiſture preſently.

That tobacco-pipe does not become a conductor by a particular degree of heat, without evaporating its moiſture, is evident, he ſays, from the following experiments.

If three or four inches of one end of a tobacco-pipe, of more than a foot in length, be made red hot, without ſenſibly heating the other end, this pipe will prove a ready conductor, through the hot air ſurrounding one part of it, and the moiſture contained in the other; although ſome part of it muſt have the degree of heat of a non-conductor. But if the whole pipe be made red hot, and ſuffered to cool till it has only ſuperficial moiſture enough to make it a good conductor, and then three or four inches of one end be again made hot, it will become a non-conductor.

If a nail be placed at, or near each end of a longiſh ſolid piece of any of the abſorbent bodies above-mentioned, ſo as the point of each nail may be about half the thickneſs of the body within its ſurface; this body, by heat, may be made a non-conductor externally or ſuperficially, while it remains a good conductor internally. For the electric fluid will readily paſs from one nail to the other, through the middle of the body, when it will not paſs on its ſurface, and even when the internal parts of the body are in an equal degree of heat with the external, as they muſt ſoon be after it begins to cool. But if the ſame

ſame body be expoſed, for a ſhort time, to a greater degree of heat than before, or if it be kept longer in the ſame heat, it will become a non-conductor intirely *.

Mr. DELAVAL, in confirmation of particular bodies requiring particular degrees of heat to render them electric or non-electric, independent of moiſture, mentions a ſubſtance which, he ſays, is affected by heat in an oppoſite manner to the former inſtances; ſince the degrees of heat, neceſſary to render the other ſubſtances electric, makes this non-electric.

THE ſubſtance was *iſland cryſtal* (which is well known for its ſingular property of a double refraction) on a piece of which he made the following obſervations. 1. After this piece of cryſtal had been rubbed, when the heat of the air was moderate, it ſhowed ſigns of electricity, though not very ſtrong ones. 2. If the heat was increaſed, ſo as to be a little greater than that of the hand, it deſtroyed its electric power intirely. 3. By cooling the ſtone again, the electric power was reſtored.

HE immerſed this piece of cryſtal into a veſſel filled with quickſilver, and ſurrounded with ice, where it remained near two hours, when the weather was very cold; and obſerved, that, upon taking it out with a pair of tongs (that it might not be altered by the

* Phil. Tranſ. Vol. lii. pt. ii. p. 459.

heat

heat of his hands) and rubbing it again, it was more ſtrongly electric then he had at any other time experienced; but that, on placing it a few minutes upon the hearth, at ſome diſtance from the fire, its electric property was again deſtroyed, for that rubbing would not occaſion any ſigns of it.

THUS, ſays he, we ſee two different kinds of fixed bodies, the one of which acquires an electric property with the ſame heat with which another loſes it; while a third ſet of ſubſtances, as glaſs, &c. retain their electricity through both the degrees of heat neceſſary to the other two.

SOME pieces of iſland cryſtal, which he had procured from different places, had not the property of loſing their electricity by a moderate heat. He had, in particular, a piece of that cryſtal, one part of which, when greatly heated, became non-electric, while the other part, with the ſame heat, or even with a much greater one, remained perfectly electric.

HE found ſeveral other earthy ſubſtances, whoſe electricity was deſtroyed by different degrees of heat.

FROM conſidering that the degree of heat, at which the iſland cryſtal firſt mentioned was in its moſt perfect electric ſtate, was leſs than the uſual heat of the air, and that a ſmall increaſe of that heat rendered it non-electric; he did not think it improbable, that many ſubſtances, which are not known to be electric,

tric, might prove ſo, if expoſed to a greater degree of cold then they have been hitherto examined in *.

To theſe obſervations Mr. Canton replies, that having formerly obſerved that the friction between mercury and glaſs in vacuo would not only produce the light of electricity, as in the luminous barometer, or within an evacuated glaſs ball, but would alſo electrify the glaſs on the outſide, he immerged a piece of dry glaſs in a baſon of mercury; and found, that by taking it out, the mercury was electrified *minus*, and the glaſs *plus*, to a conſiderable degree. He alſo found, that amber, ſealing-wax, and iſland cryſtal, when taken out of mercury, were all electrified poſitively. How then, ſays he, does it appear, that the electricity which was obſerved in rubbing the laſt mentioned ſubſtance, after it was taken out of mercury ſurrounded by ice, was owing to cold, and not to the friction between it and the mercury in taking it out. Iſland cryſtal when warm is a non-conductor, and all non-conductors may be excited with proper rubbers †.

Mr. Bergman of Upſal, in a letter to Mr. Wilſon, read at the Royal Society, April the 14th, 1761, ſays, that he had tried the experiments of Mr. Delaval with iſland cryſtal, but that the event had always been contrary to

* Phil. Tranſ. Vol. lii. pt. i. p. 354, &c.
† Ibid. pt. ii. p. 461.

what

what Mr. Delaval had reported. Trying different pieces of cryſtal, he found one which inſtead of having its virtue increaſed by cooling, was ſenſibly increaſed by heating. Afterwards trying all the reſt which he had by him, whether Swediſh cryſtal, or iſland, he found the effect to be the ſame. From this he inferred, that the cryſtals which he had were of a quite different kind from that of Mr. Delaval *.

SECTION V.

MR. CANTON's EXPERIMENTS AND DISCOVERIES RELATING TO BODIES IMMERGED IN ELECTRIC ATMOSPHERES, WITH THE DISCOVERIES OF OTHERS, MADE BY PURSUING THEM.

IN this ſection I ſhall preſent my reader with the fineſt ſeries of experiments that the whole hiſtory of electricity can exhibit, and in which we ſhall ſee diſplayed the genius and addreſs of four of the moſt eminent electricians in this whole period; viz. Mr. Canton and Dr. Franklin, Engliſhmen; and Meſſrs. Wilcke and Æpinus, foreigners. Mr. Canton had the honour to take the lead, and he made all the eſſential experiments. Doctor Franklin profeſſedly purſued them; and though *all his ſtrength he put not forth* on

* Phil. Tranſ. Vol. liii. pt. i. p. 98.

this

this occaſion, he diverſified the experiments, and made ſome improvement in the method of accounting for them. But Meſſrs. Wilcke and Æpinus in conjunction carried the experiments vaſtly farther, and completed the diſcovery; which is, certainly, one of the greateſt that has been made ſince the time of Dr. Franklin. I ſay the time of Dr. Franklin, though he himſelf be one of the perſons concerned; for by the *time of Dr. Franklin* will always be underſtood the time in which he made his capital diſcoveries in America. This will always be a diſtinguiſhed epocha in the hiſtory of electricity, from which all his own future diſcoveries will be dated.

The original experiments in this ſection, when Mr. Canton firſt publiſhed them, in his uſual conciſe, though perſpicuous manner, without any preamble, to inform us how he was led to them, exhibit ſuch a variety of attractions and repulſions of electrified bodies in different circumſtances, as looked like the power of magic; and were they conducted with a little art, I do not know any electrical experiments (made without light, or noiſe) more proper for a deception of this kind. But when they are attentively conſidered, they demonſtrate a remarkable property of all electrified bodies, which has often been referred to in the courſe of this hiſtory, but which had not been attended to before; nor indeed do I apprehend that it was fully underſtood, till it was explained in all its extent by Mr. Wilcke and Æpinus. It is, that

that the electric fluid, when there is a redundancy of it in any body, repels the electric fluid, in any other body, when they are brought within the ſphere of each other's influence, and drives it into the remote parts of the body; or quite out of it, if there be any outlet for that purpoſe. In other words, bodies immerged in electric atmoſpheres always become poſſeſſed of the electricity, contrary to that of the body, in whoſe atmoſphere they are immerged. This principle purſued led them to the method of charging a plate of air, like a plate of glaſs, and to make the moſt perfect imitation of the phenomena of thunder and lightning.

THE paper, containing an account of Mr. Canton's experiments, was read at the Royal Society, December the 6th, 1753.

MR. CANTON ſuſpended cork balls, one pair by linen threads, and another pair by ſilk; then holding the excited tube at a conſiderable diſtance from the balls with the linen thread, they ſeparated; and, upon drawing it away, they immediately came together: but he was obliged to bring the excited tube much nearer to the balls hanging by ſilk threads, before they would ſeparate; though when the tube was withdrawn, they continued ſeparate for ſome time.

As the balls in the former of theſe experiments were not inſulated, Mr. Canton obſerves, that they could not properly be ſaid to be electrified; but that when they hung within the atmoſphere of the excited tube, they might

might attract and condenſe the electric fluid round about them, and be ſeparated by the repulſion of its particles. He conjectures alſo, that the balls, at this time, contain leſs than their common ſhare of the electric fluid, on account of the repelling power of that which ſurrounds them, though ſome may be continually entering and paſſing through the threads. And if that be the caſe, he ſays, the reaſon is plain why the balls hung by ſilk in the ſecond experiment muſt be in a much more denſe part of the atmoſphere of the tube before they will repel each other. He adds, that at the approach of an excited ſtick of wax to the balls, in the firſt experiment, the electric fire is ſuppoſed to come through the threads into the balls, and to be condenſed there, in its paſſage towards the wax; ſince, according to Dr. Franklin, excited glaſs emits the electric fluid, and excited wax receives it.

WHEN two balls, ſuſpended by linen threads upon an inſulated tin tube, were electrified poſitively, and had ſeparated; he obſerved, that the approach of the excited tube would make them come nearer together; if brought to a certain diſtance, they would touch; and if brought nearer, they would ſeparate again.

IN the return of the tube, they would approach each other, till they touched, and then repel as at firſt. If the tin tube was electrified by wax, or the wire of a charged phial; the balls would be affected in the ſame man-

 ner

ner at the approach of excited wax, or the wire of the phial. If the cork balls were electrified by glaſs, their replufion would be increaſed at the approach of an excited ſtick of wax. And the effect would be the ſame, if the excited glaſs was brought towards them, when they had been electrified by wax.

THE bringing the excited glaſs to the end, or edge of the tin tube, in the former of theſe experiments, is by Mr. Canton ſuppoſed to electrify it poſitively, or to add to the electric fire it before contained; and therefore ſome will be running off through the balls, and they will repel each other. But at the approach of excited glaſs, which likewiſe emits the electric fluid, the diſcharge of it from the balls will be diminiſhed, or part will be driven back, by a force acting in a contrary direction, and they will come nearer together. If the tube be held at ſuch a diſtance from the balls, that the exceſs of the denſity of the fluid round about them above the common quantity in air, be equal to the exceſs of the denſity of that within them above the common quantity contained in cork, their repulſion will be quite deſtroyed. But if the tube be brought nearer, the fluid without being more denſe than that within the balls, it will be attracted by them, and they will recede from each other again.

MR. CANTON farther obſerves, that when the apparatus has loſt part of its natural ſtore of this fluid, by the approach of excited wax to one end of it, or is electrified negatively,

ly, the electric fire is attracted and imbibed by the balls, to ſupply the deficiency; and that more plentifully at the approach of excited glaſs, or a body poſitively electrified, than before; whence the diſtance between the balls will be increaſed, as the fluid ſurrounding them is augmented. And, in general, whether by the approach or receſs of any body, if the difference between the denſity of the internal and external fluid be increaſed, or diminiſhed; the repulſion of the balls will be increaſed, or diminiſhed accordingly.

He obſerved, that when the inſulated tin tube was not electrified, if the excited glaſs was brought towards the middle of it, the balls hanging at the end would repel each other, and the more ſo as the excited tube was brought nearer. When it had been held a few ſeconds, at the diſtance of about ſix inches, and withdrawn, the balls would approach each other till they touched; and, ſeparating again, as the tube was removed farther, would continue to repel when the tube was taken quite away. This laſt repulſion would be increaſed by the approach of excited glaſs, and diminiſhed by that of excited wax; juſt as if the apparatus had been electrified by wax, after the manner deſcribed in the laſt experiment.

He inſulated two tin tubes, which may be diſtinguiſhed by calling them A and B, ſo as to be in a line with each other, and half an inch aſunder, and at the remote end of each ſuſpended a pair of cork balls. Then, upon

bringing the excited glaſs tube towards the middle of A, and holding it a ſhort time at the diſtance of a few inches, he obſerved each pair of balls to ſeparate. Upon withdrawing the tube, the balls of A would come together, and then repel each other again, but thoſe of B would hardly be affected. By the approach of excited glaſs the repulſion of the balls of A would be increaſed, and thoſe of B diminiſhed *.

IN the former of theſe experiments, Mr. Canton ſuppoſes the common ſtock of electric matter in the tin tube to be attenuated about the middle, and to be condenſed at the ends, by the repelling power of the atmoſphere of the excited glaſs tube, when held near it. And perhaps, he ſays, the tin tube may loſe ſome of its natural quantity of the electric fluid before it receives any from the glaſs, as that fluid will more readily run off from the ends or edges of it than enter at the middle; and accordingly, when the glaſs tube is withdrawn, and the fluid is again equally diffuſed through the apparatus, it is found to be electrified negatively; ſince excited glaſs brought under the balls will increaſe their repulſion.

IN the latter of the experiments, Mr. Canton ſuppoſes that part of the fluid driven out of one tin tube enters the other, which is found to be electrified poſitively, by the decreaſing of the repulſion of its balls at the approach of excited glaſs.

* Phil. Tranſ. Vol. xlviii. pt. i. p. 350.

IT

It will readily be ſeen that, at the time theſe experiments were made, Mr. Canton retained the common idea of electric atmoſpheres; whereas it will appear by the experiments of Meſſrs. Wilcke and Æpinus (which in fact contain nothing more than thoſe of Mr. Canton) that they tend to refute the common opinion, and are much eaſier explained upon the ſuppoſition, that the portion of fluid belonging to any electrified body is conſtantly held in contact, or very nearly in contact, with the body; but acts upon the electricity of other bodies at a certain diſtance.

Dr. Franklin purſued, or rather diverſified the experiments of Mr. Canton, but retaining, likewiſe, the common opinion of electric atmoſpheres, he thought that the phenomena were more eaſily explained upon the ſuppoſition, that theſe atmoſpheres, being brought near each other, did not eaſily mix, and unite into one atmoſphere, but remained ſeparate, and repelled each other; and moreover, that an electric atmoſphere, would not only repel another electric atmoſphere, but alſo the electric fluid contained in the ſubſtance of a body approaching it, and, without joining or mixing with it, force it into the other parts of the body that contained it.

Though it muſt be difficult to aſſign a reaſon why the particles of one atmoſphere ſhould repel the particles of another atmoſphere, or of the fluid contained in another body with more force than they repel one another, or the particles of the fluid contained in

in the body to which they belong, ſince the matter is the ſame in both; yet this idea of the mutual repulſion of electric atmoſpheres, could it once be ſuppoſed, will certainly and clearly account for all the facts; and the theory pleaſes on account of its ſimplicity. But the ſame appearances will be accounted for, in a manner as ſimple and intelligible, upon the ſuppoſition, that the portion of electric fluid belonging to each body, being ſtrongly attracted by the body, is held in cloſe contact with it; but that it acts by repulſion upon the electric fluid belonging to other bodies, at a diſtance from them; and that the electric fluid doth not actually paſs out of one body into another, till it have firſt repelled the fluid out of the other body, and then be more ſtrongly attracted by the other body, than by its own; which has already got more than its natural ſhare.

THE paper containing an account of theſe experiments of Dr. Franklin was read at the Royal Society, December the 18th, 1755. His apparatus was different from that of Mr. Canton, but ſtill he exhibited the ſame effects proceeding from the ſame cauſe. He fixed a taſſel of fifteen or twenty threads, each three inches long, at one end of his prime conductor, which was five feet long and four inches in diameter, ſupported by ſilk lines. The threads were a little damp, but not wet.

IN theſe circumſtances, an excited tube brought near the end of the prime conductor, oppoſite to the threads, ſo as to give it

ſome ſparks, made the threads diverge, each thread having thereby acquired its ſeparate electric atmoſphere.

In this ſtate, the approach of the excited tube, without giving any ſparks, made the threads diverge more; but, being withdrawn, they cloſed as much; the atmoſphere of the conductor being driven by that of the tube into the threads, and returning again upon withdrawing the tube, which had then left no part of its atmoſphere behind it.

The excited tube brought under the diverging threads made them cloſe a little, having driven part of their atmoſpheres into the conductor. Upon being withdrawn, they diverged as much; that portion of their atmoſpheres which they had loſt returning again from the conductor, and the tube having left no part of its own.

The excited tube, held at the diſtance of five or ſix inches from the end of the conductor oppoſite to the threads, made them ſeparate, and, upon being withdrawn, they came together again: but if, in their ſtate of ſeparation, a ſpark was taken from the conductor near them, they would cloſe; and, upon removing the tube, would ſeparate. The tube, in both caſes, left no part of its atmoſphere behind it. It only drove the natural quantity of electricity contained in the conductor towards the threads; and part of that being taken away by the ſpark, the tube would leave the conductor and threads negative, in

which caſe, they would repel one another, as if they had been electrified poſitively.

In this ſituation, if the excited tube was brought near the conductor, they would cloſe again; the atmoſphere of the tube forcing that of the conductor into the threads, to ſupply the place of what they had loſt: but, upon withdrawing the tube, they would open again; the tube, as before, taking its whole atmoſphere away with it. When the excited tube was brought under the threads, diverging with negative electricity, they diverged more; the atmoſphere of the tube driving away more of the atmoſpheres of the threads, and giving them none in its place.

Lastly the Doctor brought the excited tube near the prime conductor, when it was not electrified; and when the threads were, thereby, made to diverge, he brought his finger near them, and obſerved, that they receded from it. This appearance had been taken notice of by Mr. Haukſbee, and others. Dr. Franklin accounts for it by ſuppoſing, that when his finger was plunged into the atmoſphere of the glaſs tube, part of its natural electricity was driven back, through his hand and body, ſo as to leave the finger negatively electrified, as well as the threads; in which caſe they muſt neceſſarily repel one another. To confirm this hypotheſis, he held a ſlender lock of cotton, two or three inches long, near the prime conductor, electrified by excited glaſs, which made the cotton ſtretch itſelf towards

wards the conductor; and obſerved, that, in this ſtate, it would recede from the finger of his other hand, at the ſame time that it was attracted by a wire of a bottle charged poſitively *.

These experiments of Dr. Franklin, made in purſuance of thoſe of Mr. Canton, were confirmed, as I obſerved before, and carried much farther by Meſſrs. Wilcke and Æpinus.

Mr. Wilcke obſerves, that a ſmall body immerged in any electric atmoſphere, if it be touched by no other body, and be withdrawn before it be repelled, ſcarce ever ſhows any ſign of electricity; if any, it is of the ſame kind with that of the body into whoſe atmoſphere it was plunged †. If any body, communicating with the ground, he brought to this light body, while it remains immerged in the atmoſphere of the electrified body, it is firſt attracted, and then repelled by it. If a point be preſented to this light body, and afterwards withdrawn, it will be found to have acquired an electricity oppoſite to that of the electrified body. From this he concludes, that parts of non-electric bodies, plunged in electric atmoſpheres, acquire an electricity oppoſite to that of the atmoſphere in which they are plunged ‡.

He placed two large inſulated conductors with their ends oppoſite to one another, and a cork ball ſuſpended on ſilk between them; and obſerved, that, upon the application of

* Phil. Tranſ. Vol. xlix. pt. i. p. 300.
† Wilcke, p. 73. ‡ Ibid. p. 77.

the excited glaſs tube to one end of either of them, the cork ball would play between them very faſt; and if the tube were held a while at the ſame diſtance, would be at reſt. Upon withdrawing the tube, the motion of the cork ball began again, and, at length, ceaſed gradually as before. If the conductors were removed from one another, while they were within the atmoſphere of the tube, they would, upon being brought together again, give a ſpark. This experiment confirmed the demonſtration, that the part of a body which is immerged in the atmoſphere of an electrified body acquires the contrary electricity *.

But the moſt complete demonſtration of this general maxim is an experiment of Mr. Æpinus. He placed a ſmall weight upon one end of a large metallic conductor, and, by means of a ſilk ſtring, removed it from the conductor, while the end on which it reſted was immerged in the atmoſphere of an electrified body; and found that it had actually acquired a different electricity from that of the atmoſphere. If the end of the conductor, oppoſite to that on which the moveable weight was placed, was made to communicate with the earth, ſtill that part of it which was near the excited electric was affected with the oppoſite electricity. Placing the moveable weight on the oppoſite end of the conductor, when it was inſulated, he found that it had ſometimes

* Wilcke, p. 78.

acquired an electricity contrary to that of the excited electric, sometimes the same electricity, though weak, and sometimes no electricity at all *.

The same ingenious philosopher considered that the same principle must extend to glass, and all other electrics; since they, as well as conductors, contain a certain quantity of the electric fluid, in their natural state. To verify this, he took a glass tube, and electrified one end of it positively. The consequence was, that four or five inches of that end were positive; but beyond that there were two inches negative; and beyond that the tube was again positive, though weakly so. This experiment he repeated very often with the same success; as also when, instead of glass, he used a solid stick of sulphur. To account for this fact, he supposed, that the electricity communicated to the end of the tube repelled the natural quantity of the fluid in the glass to some distance. This natural quantity retiring from its former situation, he supposes to become condensed, and consequently to repel another quantity of the fluid natural to the glass from its place; and that thus the whole rod would be alternately positive and negative. The author asserts, that it was from theory only that he was led to this curious experiment, the fact exactly corresponding to what he had before deduced, as the necessary consequence of Dr. Franklin's

* Æpini Tentamen, p. 129.

principles

principles of negative and positive electricity *.

The hint of these experiments Mr. Æpinus received from those above mentioned of Mr. Wilcke; and these gentlemen, residing at the same time at Berlin, pursued these curious experiments jointly, till they were led by them to discover a method of charging a plate of air in the same manner as plates of glass had usually been charged, and to throw still more light upon the theory of the famous Leyden experiment.

In the above mentioned experiments, these gentlemen observed, that the negative state of one of the bodies depended on the opposite state of the other, which was known to be exactly the case of the two sides of a charged pane of glass; and the reason of the non-communication of the same electricity was evidently the impermeability of the glass to the electric fluid in the one case, and the impermeability of the air in the other. Upon this hint they made several attempts to give the electric shock by means of air; and at length succeeded, by suspending large boards of wood covered with tin, with the flat sides parallel to one another, and at some inches asunder. For they found, that upon electrifying one of the boards positively, the other was always negative, agreeable to the former experiment: but the discovery was made complete and indisputable by a person's touch-

* Æpini Tentamen, p. 192.

ing one of the plates with one hand, and bringing his other hand to the other plate; for he then received a ſhock through his body, exactly like that of the Leyden experiment *.

WITH this plate of air, as we may call it, they made a variety of curious experiments. The two metal plates, being in oppoſite ſtates, ſtrongly attracted one another, and would have ruſhed together, if they had not been kept aſunder by ſtrings. Sometimes the electricity of both would be diſcharged by a ſtrong ſpark between them, as when a pane of glaſs burſts with too great a charge. A finger put between them promoted the diſcharge, and felt the ſhock. If an eminence was made on either of the plates, the ſelf-diſcharge would always be made through it, and a pointed body fixed upon either of them prevented their being charged at all.

THE ſtate of theſe two plates, they excellently obſerve, juſtly repreſents the ſtate of the clouds and the earth during a thunder ſtorm; the clouds being always in one ſtate, and the earth in the oppoſite; while the body of air between them anſwers the ſame purpoſe as the ſmall plate of air between the boards, or the plate of glaſs between the two metallic coatings in the Leyden experiment. The phenomenon of lightning is the burſting of the plate of air by a ſpontaneous diſcharge, which is always made through emi-

* Wilcke, p. 97.

nences,

nences, and the bodies through which the discharge is made are violently shocked *.

This principle, they likewise thought, would explain an observation of the Abbé Nollet, that electricity was often observed to be peculiarly strong, when the room was full of company, and more particularly, when numbers of them drew near together, to see the experiments. The conductor was then in one state, and the company in another; so that, constituting a large surface, when any of them took a spark, as he thereby discharged the electricity of all the company, he would feel it more sensibly than if he had stood single †.

This discovery, of the method of giving the electric shock by means of a plate of air, may be reckoned one of the greatest discoveries in the science of electricity since those of Dr. Franklin. It is beautiful to observe how this fine discovery took its rise from the experiments of Mr. Canton. Mr. Canton's experiments were pursued by Dr. Franklin, and those of Dr. Franklin, pursued by these gentlemen, produced the discovery. It is one and the same principle that, in different circumstances, accounts for this beautiful series of experiments.

This experiment of charging a plate of air is likewise related by Mr. Æpinus, who says that he was led to the discovery, by rea-

* Wilcke, p. 101. † Ibid. p. 96, &c.

soning

ſoning from the conſequences of Dr. Franklin's theory.

From theſe experiments he was alſo led to form a more diſtinct idea of the impermeability of glaſs to the electric fluid. For ſince a plate of air might be charged as well as a plate of glaſs, that property, whatever it be, muſt be common to them both; and could not, as Dr. Franklin once ſuppoſed, be any thing peculiar to the internal ſtructure of glaſs. Impermeability, he, therefore, infers, muſt be common to all electrics; and ſince they can all receive electricity by communication to a certain degree, it muſt conſiſt in the difficulty and ſlowneſs with which the electric fluid moves in their pores; whereas, in perfect conductors, it meets with no obſtruction at all *.

It was chiefly this courſe of experiments, alſo, that led Mr. Æpinus to deny the exiſtence of electric atmoſpheres, conſiſting of effluvia from electrified bodies.

He ſeems, however, to conſider this as a bold opinion; ſince he herein differs, as he ſays, from all the electricians who had written before him, and even from Dr. Franklin himſelf. Though the common opinion, he ſays, is by no means countenanced by the general principles of this theory, which ſuppoſe the electric fluid to move with difficulty through every electric ſubſtance like the air.

To thoſe who might ſay, that an electric atmoſphere is a thing obvious to the ſenſes,

* *Æpini Tentamen*, p. 82.

and

and no matter of theory; ſince it may be felt like a ſpider's web upon the hands or face; he replies, that this feeling, together with the ſulphureous ſmell of electrified bodies, are only ſenſations excited by the action of the fluid in the electrified bodies upon the electric fluid in the noſtrils, or the hand; or upon thoſe parts of the body themſelves in an unelectrified ſtate; and that they are not felt by a perſon who is not poſſeſſed of the ſame kind and degree of electricity.

He, therefore, thinks there never was any ſufficient reaſon to admit thoſe atmoſpheres; and declares, that whenever he uſes the word, he means no more by it than the *ſphere of action* of the electricity belonging to any body. Or, he ſays, the neighbouring air, which is electrified by it, may be ſo called.

But that theſe atmoſpheres have little effect in electrical experiments, he ſays, is evident from this circumſtance; that if it be blown upon with a pair of bellows, the electricity of the body which it ſurrounds is not ſenſibly diminiſhed. The electric fluid, he ſuppoſes, to reſide wholly in the electrified body, and from thence to exert its attraction or repulſion to a certain diſtance *.

The ſubject of electric atmoſpheres had not eſcaped the attention of the accurate Signior Beccaria, who was probably prior to Mr. Æpinus in ſuppoſing, that electrified bodies have no other atmoſphere than the electricity commu-

* Æpini Tentamen, p. 257.

nicated

nicated to the neighbouring air, and which goes with the air, and not with the electrified bodies, agreeable to that curious discovery of his mentioned above.

He also mentions an experiment, which, he thinks, directly proves, that all the electricity communicated to any body adheres to its surface, and does not spread into the air. He electrified a large conductor of gilt paper, in which the gilding was, in several places, taken off quite round; and observed that whenever he discharged it, by taking a spark at the end, other sparks were visible at all the interruptions; the charge of the more remote parts having come off through the substance of the metal, and not along the air; as the greatest part of it, at least, might have done, if it had lodged there *.

It is now also Mr. Canton's opinion, that electric atmospheres are not made of effluvia from excited or electrified bodies, but that they are only an alteration of the state of the electric fluid contained in, or belonging to the air surrounding them, to a certain distance; that excited glass, for instance, repels the electric fluid from it, and consequently, beyond that distance makes it more dense; whereas excited wax attracts the electric fluid existing in the air nearer to it, making it rarer than it was before.

This will be best understood by a figure. Let A (Pl. I. fig. 1.) represent unexcited glass

* Elettricismo artificiale, p. 54.

or wax. B excited glaſs, and C excited wax; and let the dots on each ſide of A repreſent a line of particles of the electric fluid at their proper diſtance in a natural ſtate.

LET B and C be carried about where you will in the air, B will make an atmoſphere equally denſe, and C an atmoſphere equally rare, while the quantity of the electric fluid each of them contains is the ſame as at firſt. When any part of a conductor comes within the atmoſphere of B, the electric fluid it naturally contains will be repelled by the denſe atmoſphere, and will recede from it. But if any part of a conductor be brought within the atmoſphere of C, the electric fluid it naturally contains will be attracted by the rare atmoſphere, and move towards it. And thus may the electric fluid contained in any body be condenſed or rarefied; and if the body be a conductor, it may be condenſed or rarified in any part of it, and ſome may be eaſily drawn out of, or an additional quantity put into it.

IT was obſerved before, that an experiment of Dr. Franklin, which he thought proves that electric atmoſpheres did not exclude the air, might juſtly make us ſuſpect the exiſtence of thoſe atmoſpheres, ſince the electric matter is known to repel the air. Another experiment of the ſame nature was made by Dr. Darwin of Litchfield, who ſent an account of it to the Royal Society, which was read May the 5th, 1757. He got a glaſs tube, open at one end, and having a ball at the other. This ball and half of the tube he coated; and when he had inverted

inverted it, and dipped a confiderable part of it into a veffel containing oil of turpentine, he introduced a wire into it, and charged it; and obferved, that the oil did not at all appear to fubfide. From this he concluded, that the electric atmofphere, flowing round the wire and the coating the tube, above the oil, did not difplace the air, but exifted in its pores *.

An experiment fimilar to that of Dr. Franklin and that of Dr. Darwin was made by Signior Beccaria. He took a coated phial, and when he had inferted into it a fmall glafs tube, bent horizontally when it came out of the phial; he clofed it with cement, and prefented light afhes to the extremity of the tube, the orifice of which was very fine; and always found, that the afhes were blown off, when a fpark was taken into the phial, but they returned towards the end of the tube afterwards †. It is probable, that the metal not being fufficiently in contact with the infide coating, a fpark was made in the infide, which expelled the air, and caufed the motion in the afhes. The faireft method of trying it would be with a phial, in which the metal that received the fire from the conductor, fhould be a production of the inward coating.

* Phil. Tranf. Vol. l. pt. i. p. 351.
† Lettere dell' electricifmo, p. 79.

SECTION VI.

MR. SYMMER'S EXPERIMENTS RELATING TO THE TWO ELECTRICITIES, AND THOSE MADE BY JOHANNES FRANCISCUS CIGNA IN PURSUANCE OF THEM.

IT had hitherto been univerfally fuppofed, that all the phenomena of electricity were produced by the action of one electric fluid. Even Mr. Du Fay, at the time that he imagined he had difcovered another electric fluid, diftinct from that of glafs, and peculiar to rofin, &c. thought, however, that it was quite independent of the other, and that their operations were never combined. Dr. Watfon, and Dr. Franklin thought it was very evident, that the difference between the two electricities confifted in the one being a redundancy, and the other a deficiency of the fame matter. And all the experiments that had been made concerning the two electricities feemed to confirm this hypothefis. At length, however, Mr. Symmer produces a great number of curious experiments, relating to the fame fubject; and infers from them the probable exiftence of *two electric fluids*, not independent, but always co-exiftent, and counteracting one another.

THE firft fet of his experiments are very remarkable, but he does little more than relate naked facts. They were diverfified, and

 purfued

pursued much farther by Mr. Cigna, of Turin, who has also explained them upon the principles of Dr. Franklin's theory; though he was of opinion, that no experiments that had yet been made were decisive in favour of either of the two hypotheses. Few histories of experiments are more entertaining than the first of these of Mr. Symmer; the subsequent experiments are less satisfactory. The papers relating to them all were read at the Royal Society in the year 1759 *.

THIS gentleman had for some time observed, that upon putting off his stockings, in an evening, they made a crackling or snapping noise, and that, in the dark, he could perceive them to emit sparks of fire. He had no doubt but that this proceeded from the principle of electricity, and, after a great number of observations, to determine on what circumstances those strong electrical appearances depended, he found, at length, that it was the combination of white and black that produced the electricity; and that the appearances were the strongest when he wore a white and black silk stocking upon the same leg †. These, however, discovered no sign of electricity while they were upon the

* Phil. Transf. Vol. li. pt. i. p. 340.

† The Abbé Nollet, in repeating these experiments of Mr. Symmer, found, that it was not absolutely necessary, that one of the stockings should be black, for that, if one of them was only dipped in a decoction of gall-nuts, which doth not dye them black, but is only a preparative to it, it would have the same effect. Nollet's Lettres, Vol. iii. p. 42.

leg, or hand (for he found that his hand was sufficient) though they were drawn backwards and forwards upon it several times. Nor when taken from the hand, and presented to an electrometer (i. e. Mr. Canton's balls) did they appear to have acquired any more than a very small degree of electricity; but the moment they were separated, they were found, both of them, to be highly electrified, the white positively, and the black negatively.

BOTH the stockings, when held at a distance from one another, appeared inflated to such a degree, that, when highly electrified, they exhibited the intire shape of the leg; and when two black, or two white stockings were held together, they would repel one another, so as to form an angle, seemingly, of thirty or thirty-five degrees.

WHEN a white and black stocking were presented to each other; they would be mutually attracted; and, if permitted, would rush together with surprising violence. In their approach their inflation gradually subsided, and their attraction of foreign objects diminished, but their attraction of one another increased. When they actually met, they grew flat, and joined as close together, as if they had been so many folds of silk. When they were separated, their electricity did not seem to have been in the least impaired by the shock of meeting; for they would be again inflated, attract, repel, and rush together as before.

WHEN

When this experiment was performed with two black ſtockings in one hand, and two white ones in the other, it exhibited a curious ſpectacle. The repulſion of thoſe of the ſame colour and the attraction of thoſe of different colours, threw them into an agitation which was not unentertaining, and made them catch each at the oppoſite colour, at a greater diſtance than could have been expected.

When the ſtockings were ſeparated from one another, they would loſe their power very ſoon, much like the excited tube; but when they were together, they would retain it an hour or two, or longer, if the air was favourable to electricity. The ſharpeſt metallic point could not deprive them of it; and when they were one within the other, no means he could think of could procure the leaſt perceivable diſcharge of the electricity. In this reſpect, Mr. Symmer thought there was a conſiderable reſemblance between the black and the white ſtocking, when put within one another, and the Leyden phial.

What was ſtill more remarkable in theſe experiments with the white and black ſtockings, was the power of electrical coheſion which they exhibited. Mr. Symmer perceived that the white and black ſtockings, when electrified, and allowed to come together, not only joined extremely cloſe, but actually ſtuck to each other. By means of a balance, he found, that in order to ſeparate them, it required from one to twelve ounces. Another

time they raiſed ſeventeen ounces, which was twenty times the weight of that ſtocking which ſupported them, and this in a direction parallel to its ſurface.

WHEN one of the ſtockings was turned inſide out, and put within the other, it required twenty ounces to ſeparate them, though when they were applied to each other externally, ten ounces were ſufficient.

GETTING the black ſtockings new dyed, and the white ones waſhed, and whitened in the fumes of ſulphur; and then putting them one within the other, with their rough ſides together, it required three pounds three ounces to ſeparate them. And he had reaſon to think that the ſulphur contributed nothing to the experiment.

TRYING this experiment with ſtockings of a more ſubſtantial make, he found the effects more conſiderable. When the white ſtocking was put within the black one, ſo that the outſide of the white was contiguous to the inſide of the black, they raiſed nine pounds wanting a few ounces, which was fifty times the weight of the ſtocking. When the white ſtocking was turned inſide out, and put within the black one, ſo that their rough ſurfaces were contiguous, they raiſed fifteen pounds one pennyweight and a half, which was ninety-two times the weight of the ſtocking.

HAVING cut off the ends of the thread, and the tufts of ſilk, which had been left in the inſide of the ſtockings, the coheſion was conſiderably diminiſhed. Preſſing them together

gether between his hands contributed much to ſtrengthen it *.

When the white and black ſtocking were in coheſion, and another pair, more highly electrified were ſeparated from one another, and preſented to the former, their coheſion would be diſſolved; and each ſtocking of the ſecond pair would catch hold of, and carry away with it, that of its oppoſite colour. If the degree of electricity of both pairs were equal, the coheſion of the former pair would be weakened, but not diſſolved; and all the four would cohere, forming one maſs. If the ſecond pair were but weakly electrified, the coheſion of the firſt pair would be but little impaired, and the coheſion of the whole maſs would be ſmall in proportion.

Mr. Symmer alſo obſerved, that white and black ſilk, when electrified, not only cohered with each other, but would alſo adhere to bodies with broad, and even with poliſhed ſurfaces, though thoſe bodies were not electrified. This he diſcovered accidentally, having, without deſign, thrown a ſtocking out of his hand, which ſtuck to the paper hangings of the room. He repeated the experiment, and found it would continue hanging near an hour.

Having ſtuck up the black and white ſtockings in this manner, he came with another pair of ſtockings highly electrified; and applying the white to the black, and the

* Phil. Tranſ. Vol. li. pt. i. p. 393.

black

black to the white, he carried them off from the wall, each of them hanging to that which had been brought to it.

THE ſame experiments held with the painted boards of the room, and likewiſe with the looking-glaſs, to the ſmooth ſurface of which both the white and the black ſilk appeared to adhere more tenaciouſly than to either of the former *.

A FEW obſervations, ſimilar to ſome of theſe of Mr. Symmer, were made by Signior *Aleſſandro Amadeo Vaudonià*, a friend of Signior Beccaria. He put a beaver ſhirt between two others, which he wore in extreme cold weather; and whenever he put off the uppermoſt ſhirt, which he did every day, he found it adhered to the beaver ſhirt, and, on the ſeparation, electric ſparks were viſible between them. Whenever he put off the beaver ſhirt, it adhered ſtill more to the under ſhirt, and when held at a conſiderable diſtance from it, would ruſh to it. Theſe attractions would be repeated many times, but they grew more languid by degrees, till they intirely ceaſed. Signior Beccaria, upon hearing of this experiment, repeated it with ſome variation, and found it to anſwer on himſelf †.

THE coheſion of the two ſtockings induced Mr. Symmer to try the force of electrical coheſion in electrified panes of glaſs. For this purpoſe, he got two panes of common window glaſs, the thinneſt and the ſmootheſt that he

* Phil. Tranſ. Vol. li. pt. i. p. 366.
† Dell' elettricismo artificiale, p 197.

could

could find, and coated one of the ſides of each with tinfoil, leaving a ſpace uncovered near the edges. He then put the uncovered ſides together, and charging them both as one pane, he found, as he expected, that their coheſion was conſiderably ſtrong: but he had no apparatus to meaſure the ſtrength of it. He then turned the plates upſide down, and found that the ſame operation which had before charged them, did now uncharge them, according to the analogy of the Leyden phial.

PLACING two panes of glaſs, each of them coated on both ſides, one upon the other, he found that they were both charged ſeparately, and that there was no coheſion between them.

IN purſuance of theſe laſt mentioned experiments of Mr. Symmer, and another made at Pekin (which will be recited preſently) Signior Beccaria made the following, which are very curious; but which, after the example of the author, I ſhall relate without attempting an explanation.

HAVING charged a coated plate of glaſs, he ſlipped the coating from off the negative ſide, and applied another, uncoated and uncharged plate of glaſs cloſe to it. After this, putting a coating upon the uncharged glaſs (ſo that the whole reſembled one coated plate, conſiſting of two *laminæ)* he formed a communication between the coatings. The conſequence was an exploſion, and a coheſion of the plates.

IF

If he ſeparated the plates before the exploſion, after they had been in conjunction ſome time, the charged plate was poſitive on both ſides, and the uncharged plate negative on both ſides. But if he ſeparated them after the exploſion, the charged plate was negative on both ſides, and the uncharged plate poſitive on both ſides.

If after the exploſion he ſeparated and joined them again alternately, a ſmall circle of paper, placed under the uncharged plate, adhered to it upon every ſeparation, and was thrown off again upon every conjunction. This he could repeat even five hundred times, with once charging the plate. This was the experiment that he ſays was made by ſome Jeſuits at Pekin, in the year 1755, and being ſent to the Academy of Sciences at Peterſburgh, was publiſhed in their Memoirs, vol. viii. p. 276.

If, in theſe experiments, the charged plate was inverted, and the poſitive ſide applied to the uncharged plate, all the effects were exactly the reverſe of the former. If it was inverted ever ſo often, after remaining ſome time in contact with the uncharged glaſs, it would produce a change in the electricity. In the dark, a light was always ſeen upon the ſeparation of theſe plates.

Laying the two plates together, like one plate, and coating the outſides of them, he charged them both together, and, at the diſtance of about four feet, he diſtinguiſhed ſix of the *coloured rings*, which Newton deſcribes in his book of Optics, all parallel to one another,

other, and nearly parallel to the edge of the coating. At the angles of the coatings the rings ſpread to a greater diſtance; where the coatings did not quite touch the glaſs, the rings bent inwards; and where the coatings adhered very cloſe, they retired farther from them. Upon diſcharging theſe two plates, the coloured rings vaniſhed, and the electric coheſion (which Mr. Symmer had obſerved in this caſe) ceaſed with them.

Upon ſeparating theſe plates before the exploſion, that which had received the poſitive electricity was poſitive on both ſides, and the other negative on both ſides. If they were ſeparated after the exploſion, each of them (as in the former experiment) was affected in a manner juſt the reverſe of this. Upon inverting theſe plates, that which was the thinner appeared to be poſſeſſed of the ſtronger electricity, and (like the charged plate in the former experiment) brought the other to correſpond to it.

Charging the two plates ſeparately, and taking off two of the coatings, ſo as to place the two poſitive or the two negative ſides together, there was no coheſion or exploſion. But joining a poſitive and a negative ſide, they cohered, and a communication being formed on the outſide, there was an exploſion, which increaſed the coheſion. Making the abovementioned experiments with theſe plates, he ſays, they acted juſt as the two that were charged at the ſame time*.

* Phil. Tranſ. Vol. lvii. p. 458.

Mr.

MR. SYMMER concludes his account of these experiments with declaring it be his opinion, that there are two electric fluids, or emanations of two distinct electric powers, essentially different from each other; that electricity does not consist in the afflux and efflux of these fluids, but in the accumulation of the one or the other of them in bodies electrified; or, in other words, it consists in the possession of a larger portion of one or the other power, than is requisite to maintain an even balance within the body; and lastly, that, according as the one or the other power prevails, the body is electrified in the one or the other manner. Nor will this principle, says he, of two distinct electrical powers be found, upon due consideration, to disagree with the general system of nature. It is one of the fundamental laws of nature, that action and reaction are inseparable and equal; and, when we look round, we find that every power which is exerted in the material world meets with a counteracting power, which controuls and regulates its effects, so as to answer the wise purposes of providence *.

MR. SYMMER also alledges, in proof of his two distinct powers of electricity, the experiment which Dr. Franklin has related, of piercing a quire of paper with an electric shock. He thought that the bur which was raised on both sides of the paper was produced by two fluids, moving in two different direc-

* Phil. Transf. Vol. li. pt. i. p. 389.

tions.

tions. To ſhow the manner in which this ſtroke was made more evidently, he mentions two other ſimilar experiments, in which the circumſtances of the ſtroke were a little varied.

A PIECE of paper, covered on one ſide with Dutch gilding, and which had been left accidentally between two leaves, in a quire of paper in which the former experiment had been made, was found to have the impreſſion of two ſtrokes upon it, about a quarter of an inch from each other; the gilding being ſtripped off, and the paper left bare for a little ſpace in both places. In the center of one of theſe places was a little round hole, in the other only an indenture or impreſſion, ſuch as might have been made with the point of a bodkin.

THESE obſervations Mr. Symmer communicated to Dr. Franklin, who, notwithſtanding Mr. Symmer was endeavouring to eſtabliſh a theory of electricity contrary to his own, with the generoſity natural to him, aſſiſted him with his apparatus in making another experiment in purſuance of that mentioned above.

IN the middle of a paper book, of the thickneſs of a quire, Mr. Symmer put a ſlip of tinfoil; and in another, of the ſame thickneſs, he put two ſlips of the ſame ſort of foil, including the two middle leaves of the book between them. Upon ſtriking the two different books, the effects were anſwerable to what he expected. In the firſt, the leaves on each

each ſide of the foil were pierced, while the foil itſelf remained unpierced; but, at the ſame time, he could perceive an impreſſion had been made on each of its ſurfaces, at a little diſtance from one another; and ſuch impreſſions were ſtill more viſible on the paper, and might be traced, as pointing different ways. In the ſecond, all the leaves of the book were pierced, excepting the two that were between the ſlips of foil; and in theſe two, inſtead of holes, the two impreſſions in contrary directions were viſible.

MR. SYMMER afterwards got an electrical apparatus of his own, formed on the model of that of Dr. Franklin, with which he frequently repeated the experiments above-mentioned, the reſult of all which he compriſes in the three following obſervations.

1. WHEN a quire of paper, without any thing between the leaves, is pierced with a ſtroke of electricity, the two different powers keep in the ſame track, and make but one hole in their paſſage through the paper: not but that the power from above, or that from below, ſometimes darts into the paper at two or more different points, making ſo many holes, which, however, generally unite before they go through the paper. They ſeem to paſs each other about the middle of the quire, for there the edges are moſt viſibly bent different ways; whereas, in the leaves near the outſide of the quire, the holes very often carry more the appearance of the paſſage of a power iſſuing out, and exploding

ploding into the air, than of one darting into the paper.

2. When any thin metallic ſubſtance, ſuch as gilt leaf, or tinfoil, is put between the leaves of the quire, and the whole is ſtruck, in that caſe, the counteracting powers deviate from the direct tract, and leaving the path which they would in common have taken through the paper, only make their way in different lines to the metallic body, and ſtrike it in two different points, diſtant from one another about a quarter of an inch, more or leſs; the diſtance appearing to be the leaſt when the power is greateſt: and whether they pierce it, or only make impreſſions upon it, in either caſe they leave evident marks of motion from two different parts, and in two contrary directions. It is this deviation from a common courſe, and the ſeparation of the lines of direction conſequent upon it, ſays he, that affords a proof of the exertion of two diſtinct and counteracting powers.

3. When two ſlips of tinfoil are put into the middle of the quire, including two or more leaves between them, if the electricity be moderately ſtrong, the counteracting powers only ſtrike againſt the ſlips, and leave their impreſſion there. When it is ſtronger, one of the ſlips is generally pierced, but ſeldom both; and from what he had obſerved in ſuch caſes, he ſays it ſhould ſeem, as if the power which iſſued from the outſide of the phial acted more ſtrongly than that which proceeded from within, for the lower ſlip was moſt com-

monly pierced. But this, he adds, may be owing to the greater ſpace which the power from within has to move through before it ſtrikes the paper *.

In the ſame paper, Mr. Symmer furniſhes a remarkable inſtance of the power of an hypotheſis in drawing facts to itſelf, in making proofs out of facts which are very ambiguous, and in making a perſon overlook thoſe circumſtances in an experiment which are unfavourable to his views.

When a phial is electrified but a little, Mr. Symmer ſays, if we touch the coating of it with a finger of one hand, and, at the ſame time, bring a finger of the other hand to the wire, we ſhall receive a pretty ſmart blow upon the tip of each of the fingers, the ſenſation of which reaches no farther. If the phial be electrified a degree higher, we ſhall feel a ſtronger blow, reaching to the wriſts, but no farther. When, again, it is electrified to a ſtill higher degree, a ſeverer blow will be received, but will not be felt beyond the elbows. Laſtly, when the phial is ſtrongly charged, the ſtroke may be perceived in the wriſts, and elbows; but the principal ſhock is felt in the breaſt, as if a blow from each ſide met there. This plain and ſimple experiment, ſays Mr. Symmer, ſeems obviouſly to ſuggeſt to obſervation the exiſtence of two diſtinct powers, acting in contrary directions; and, I believe, ſays he, it would be held as a

* Phil. Tranſ. Vol. li. pt. i. p. 377, &c.

 ſufficient

ſufficient proof by any perſon, who ſhould try the experiment, with a view to determine the queſtion ſimply from his own perceptions *.

It is a ſufficient anſwer to this remark of Mr. Symmer, that if twenty people join hands, they may all be made to feel the ſhock in their wriſts, or their elbows, without having their breaſts affected in the leaſt. And can it be ſuppoſed, that the two currents of electric fire could come at all their wriſts or elbows, without paſſing through their breaſts? According to Mr. Symmer's hypotheſis, it ſhould ſeem, that, in a large circle, thoſe perſons only who ſtood near the phial, on either hand, ſhould feel *a ſmall ſhock*; that a few perſons more, at each extremity of the circle, ſhould feel one ſomething ſtronger; and that it could only be a very ſtrong ſhock, which could at all affect the perſon who ſtood in the middle; and that then he ſhould be affected the leaſt of any perſon in the company. But all theſe conſequences are contrary to fact.

This hypotheſis of Mr. Symmer, notwithſtanding he has failed in his application of it to the experiments above mentioned, has attracted the notice of ſeveral electricians, both at home and abroad; and ſome perſons ſeem inclined to adopt it, in preference to Dr. Franklin's theory. I ſhall therefore conſider it more at large, when I come to treat of *theories*

* Phil. Tranſ. Vol. LI. pt. i. p. 373, &c.

professedly; till which time, I take leave of this ingenious philosopher, and his two electric fluids.

THE experiments of Mr. Symmer excited the attention of Mr. Cigna, and led him to a course of experiments, which throws still more light, both upon the doctrine of the two electricities and the Leyden phial. They are also a farther illustration of the discovery of Mr. Canton, improved by Messrs. Wilcke and Æpinus, of the mutual repellency of similar electric atmospheres.

HE took two white silk ribbons, just dried at the fire, and having extended them upon a smooth plain, either a conductor or a non-conductor, he drew over them the sharp edge of an ivory ruler, and found, that both the ribbons had acquired electricity enough to adhere to the plain; though, while they remained upon the plain, they shewed no other sign of it. If they were both taken off from the plain together, they attracted one another, the upper having acquired the resinous and more powerful, and the lower the vitreous and weaker electricity. If they were taken up separately, they repelled one another, having both acquired the resinous electricity *.

IN this separation of both the ribbons from the plain, as also in their separation, afterwards, from one another, electric sparks were visible between them; but if they were

* Memoirs of the Academy at Turin for the year 1765, p. 31.

again

again put upon the plain, or joined together, no light appeared upon their second separation, without another friction of the ruler. Also, when, by being taken off separately, they had been made to repel one another, if they were laid on the plain again, and taken off together, they would not attract; and if, by being taken off together, they had first been made to attract one another, and were laid on the plain a second time, and then taken off separately, they would not repel, without another friction.

When, by the operation above mentioned, they had acquired the same electricity, if they were placed, not upon the smooth body on which they had been rubbed, but on a rough one, and a conductor, as hemp or cotton, not very dry; they would, upon being separated, show contrary electricities; which, when they were joined together, would disappear as before *.

If they had been made to repel one another, and were afterwards placed one upon the other, on the rough surface above mentioned, they would, in a few minutes, attract one another; the lower of the two ribbons having changed its resinous into a vitreous electricity.

If the two white ribbons received their friction upon the rough surface, they always acquired contrary electricities; the upper of the two having the resinous, and the lower

* Memoirs of the Academy at Turin for the year 1765, p. 33.

the vitreous, in whatever manner they were taken off.

The ſame thing that was done by a rough ſurface was done by any pointed conductor. If two ribbons, for inſtance, were made to repel, and hang parallel to one another; and the point of a needle were drawn oppoſite to one of them, along its whole length, they would preſently ruſh together; the electricity of that ribbon to which the needle was preſented being changed into the contrary *.

In the ſame manner in which one of the ribbons changed its electricity, a ribbon not electrified would acquire electricity, viz. by putting it upon a rough ſurface, and laying an electrified ribbon upon it; or by holding it parallel to an electrified ribbon, and preſenting a pointed conductor to it.

He placed a ribbon not quite dry under another that was well dried at the fire, upon a ſmooth plain; and when he had given them the uſual friction with his ruler, he found that, in what manner ſoever they were removed from the plain, the upper of them had acquired the reſinous, and the lower the vitreous electricity †.

If both the ribbons were black, all the above mentioned experiments ſucceeded, in the ſame manner as if they had been white ‡.

* Memoirs of the Academy at Turin for the year 1765, p. 34. † Ibid, p. 35. ‡ Ibid.

If, inftead of his ivory ruler, he made ufe of any fkin, or of a piece of fmooth glafs, the event was the fame; but if he made ufe of a ftick of fulphur, the electricities were, in all cafes, the reverfe of what they were before; the ribbon which was rubbed having always acquired the vitreous electricity.

When he made ufe of paper, either gilt or not gilt, the refults were uncertain.

When the ribbons were wrapped in paper, gilt or not gilt, and the friction was made upon the paper, laid upon the plain above mentioned, the ribbons acquired, both of them, the refinous electricity *.

If the ribbons were one black, and the other white, which ever of them was laid uppermoft, and in whatever manner the friction was made, the black generally acquired the refinous, and the white the vitreous electricity †.

He obferved, however, the following conftant event; that whenever the texture of the upper piece of filk was loofe, yielding, and retiform, like that of a ftocking, fo that it could move, and be rubbed againft the lower, and the rubber was of fuch a nature as to impart but little electricity to glafs; the electricity which the upper piece of filk acquired, did not depend upon the rubber, but upon the body it was laid upon; in which cafe the black was always refinous, and the white vi-

* Memoirs of the Academy at Turin for the year 1765, p. 36. † Ibid. p. 38.

treous. But when the ſilk was of a cloſe texture, hard and rigid, and when the rubber was ſuch as imparted a great degree of electricity to glaſs, the electricity of the upper piece did not depend upon the lower, but upon the rubber. Thus a white ſilk ſtocking, rubbed with gilt paper upon glaſs, became reſinous, and the glaſs vitreous; but if a piece of ſilk, of a firmer texture, was laid upon a plate of glaſs, it always acquired the vitreous electricity, and the glaſs the reſinous, if it was rubbed with ſulphur; and for the moſt part, if it was rubbed with gilt paper *. So that the ſilk that was rubbed received its electricity, ſometimes from the rubber, and ſometimes from the ſubſtance placed under it; according as it received greater friction from the one or the other, or in proportion as one or the other was more proper to give electricity to glaſs..

Another ſet of experiments, which the ſame Mr. Cigna made, illuſtrate the adheſion of Mr. Symmer's electrical ſtockings to bodies with ſmooth ſurfaces. He inſulated a plate of lead, and bringing an electrified ribbon near it, obſerved that it was attracted very feebly. Bringing his finger to the lead, a ſpark iſſued out of it, upon which it attracted the ribbon vigorouſly, and both together ſhewed no ſigns of electricity. Upon the ſeparation of the ribbon, they again both ap-

* Memoirs of the Academy at Turin, for the year 1765, p. 40.

peared

peared to be electrified, and a spark was perceived between the plate and the finger *.

LAYING two plates of glass upon a smooth conductor communicating with the ground, and rubbing them in the same manner as the ribbons had been rubbed, they likewise acquired electricity, and adhered firmly, both to one another, and to the conductor. If it were a plate of lead, not very thick, it would be supported by the attraction. When they were together, they showed no other signs of electricity †.

WHEN the two plates of glass were separated from the conductor, and kept together, they showed, on both sides, a vitreous electricity; and the conductor, if it had been insulated, was seen to have contracted a resinous electricity.

THE two plates of glass themselves, when separated, were possessed of the two electricities; the upper of the vitreous and stronger, and the lower of the resinous and weaker.

WITH a rough conductor, whether they were originally rubbed upon it, or brought to it, after they had been rubbed upon a smooth one, they scarce contracted any electricity; though, when they were separated from one another, they were affected as before.

UPON this principle, Mr. Cigna endeavours to account for the non-excitation of a globe

* Memoirs of the Academy at Turin, for the year 1765, p. 43. † Ibid, p. 52.

or tube from which the air is exhausted, or which is lined with conducting substances. In this case, he says, the vitreous electricity on the external surface of the glass is balanced by the resinous in the inward coating, or in the vacuum which serves instead of a coating; and therefore it is in the situation of the plates of glass while they lie upon the conductor above-mentioned: but when the inward coating is taken away, the electricity appears on the outside, without any fresh excitation, as when the plates were removed from the conductor *.

When he laid a number of ribbons of the same colour upon the smooth conductor, and drew his ruler over them; he found, that when he took them up singly, they all gave sparks, at the place where they were separated, as the last ribbon did with the smooth plate, and had all acquired the resinous electricity †.

If they were all taken from the plate together, they cohered in one mass, which, on both sides, appeared to be resinous. If they were laid upon the rough conductor, in the same order (whereby the opposite electricities were brought to an equilibrium) and they were all separated singly, beginning with the lowest, sparks appeared as before; but all the ribbons had acquired the vitreous electricity, except the uppermost, which retained

* Memoirs of the Academy at Turin, for the year 1765, p. 54. † Ibid. p. 61.

the

the resinous electricity it had received from the friction *.

If they received the friction upon the rough conductor, and were all taken up at once (in order to have a bundle in which the opposite electricities were balanced) all the intermediate ribbons acquired the electricity, either of the highest or the lowest ribbon, according as the separation was begun with the highest, or the lowest.

If two ribbons were separated from the bundle at the same time, they clung together; and, in that state, showed no sign of electricity, as one of them alone would have done. When they were separated, and the different electricities were manifest, the electricity was observed to reside in the outermost, and was opposite to that by which they had both adhered to the bundle, but much weaker †.

He placed a number of ribbons upon a plate of metal, which received electricity from the globe, while he held a pointed body to the other side of the ribbons. The consequence was, that all the ribbons became possessed of the electricity opposite to that of the plate, or of the same, according as they were taken off; except the most remote, which always kept an electricity opposite to that of the plate.

From these experiments he infers, that as electricity is propagated from the outermost

* Memoirs of the Academy at Turin, for the year 1765, p. 61. † Ibid.

ribbon

ribbon to thoſe underneath it, or elſe from the plate below to thoſe next above it, when they are ſeparated, ſo likewiſe when the coating is ſeparated from a charged pane of glaſs, it likewiſe depoſits its electricity upon the ſuperficies of the glaſs, the phenomena being the ſame in both. For when he put metal coatings on the ſide of a plate of glaſs, without any cement, they adhered firmly to the glaſs when it was charged, and a light appeared upon their being ſeparated from it, as in the caſe of the ribbons *.

WHEN he coated a number of ribbons in the ſame manner, and charged them, the coatings adhered firmly to the ribbons; but he could never ſeparate one of them, but (in conſequence of the looſe texture of the ſilk) a ſpark would go to the oppoſite coating, which immediately fell off, the whole being then diſcharged †.

BUT he thought the coatings did not depoſite all their electricity on the plate, when they were taken off; for though, when both were taken off, the electricities of the two ſides ſtill balanced one another (becauſe each retained the ſame diminiſhed quantity) yet, when one ſuperficies of the glaſs, or of the ribbons, received its electricity from friction, and the other only from the oppoſite coating, he obſerved, that the electricities which balanced one another while the coating was on, were no longer balanced when it was taken off;

* Memoirs of the Academy at Turin, for the year 1765, p. 63. † Ibid p. 64.

the

the electricity of the ſurface which was rubbed then prevailing, becauſe the conducting coating had, upon its ſeparation, taken part of its electricity along with it *.

To confirm this, he adds another experiment. He charged a pane of glaſs, coated on one ſide, while the other received electricity by a pointed conductor from the machine: he likewiſe inverted the plate, and made the coated ſide communicate with the prime conductor, while a pointed piece of metal was preſented to the oppoſite ſide; and, in both caſes, found, that while the coating remained, the two electricities balanced one another; but that when the coating was ſlipped off, the electricity of the oppoſite ſide prevailed, ſo as to be apparent on both ſides of the plate †.

* Memoirs of the Academy at Turin for the year 1765, p. 65.
† Ibid.

SECTION

SECTION VII.

THE HISTORY OF THE LEYDEN PHIAL CONTINUED.

GREAT as were the difcoveries of Dr. Franklin concerning the Leyden phial, he left fome curious particulars for this period of the hiftory of electricity; and the fubject is by no means exhaufted. Many of the properties of this *wonderful bottle*, as the Doctor calls it, are ftill unexplained. But as more and more light is perpetually thrown upon it, let us hope that, at length, we fhall thoroughly underftand this great experiment. The greateft difcovery concerning the properties of the Leyden phial, in this period, hath already been related in the account of Meffrs. Wilcke's and Æpinus's method of giving the fhock by means of a plate of air; and other obfervations have, likewife, been occafionally mentioned, in places where their connection required them to be inferted. This fection, however, will contain feveral experiments of a mifcellaneous nature, which are well worth notice.

IMMEDIATELY upon the difcovery of the fhock given by glafs, all electricians attempted to charge other electric fubftances, but none of them fucceeded before Signior Beccaria. He found that a very fmooth plate of fealing-wax, made by pouring that fubftance, when

when melted, upon an oiled marble table, would receive a considerable charge *.

After trying several other electrics, in the same manner, he found that a mixture of pitch and colophonia was charged less than sealing-wax, but more than sulphur, and a great deal more than pitch alone †.

But the most curious experiment of this philosopher, relating to this subject, was made with a view to ascertain the real direction of the electric fluid in a discharge. He suspended a coated plate of glass by a silk thread, and having charged it, and kept it perfectly still; he observed that no motion was given to it, when the discharge was made by a crooked wire approaching both the sides at the same time. The experiment, in fact, proved the re-action of the glass upon the electric matter; whereby the plate were kept still, notwithstanding the fluid rushed with great violence from one side to the other. He compares the glass to an ivory ball placed between two others, which keeps its place, when, by an impulse given to one of them, the opposite ball flies off ‡.

Mr. Hartman of Hanover has published an account of a curious experiment, which seems to show the progressive motion of the electrical explosion. He passes a shock through a great number of cannon balls, sometimes to the number of forty, placed near one another, upon small drinking-glasses;

* Lettere dell' elettricismo, p. 64. † Ibid. p. 66.
‡ Ibid. p. 72.

when

when all the ſparks are ſeen at the ſame moment of time, and all the ſnappings make but one report. But when he ſubſtitutes eggs inſtead of the balls of metal, the progreſs of the exploſion is viſible, every two giving a ſnap and a flaſh ſeparately. This experiment requires weather very favourable to electricity, and, he ſays has generally ſucceeded the beſt with only ten or twelve eggs *. This author has not expreſsly ſaid in which direction the ſparks ran; but as he adopts Dr. Franklin's hypotheſis, it may be preſumed, that he imagined them to go from the poſitive to the negative ſide of the charged glaſs.

A VERY ingenious experiment has alſo been made by Mr. Amadeus Lullin of Geneva, in order to aſcertain the direction of the electric fluid in exploſions, and which he thinks comes nearer to the *experimentum crucis* than any other. He placed a common card in the circuit of the electrical exploſion, while the wire which communicated with the poſitive ſide of the jar lay on one ſide of it, and that which communicated with the negative ſide lay on the other, their extremities not being placed oppoſite to one another, but at ſome diſtance. Things being thus circumſtanced, he obſerved, that upon making the diſcharge, the card was conſtantly pierced cloſe to the extremity of the wire which communicated with the negative ſide of the jar,

* Abhandlung, p. 58, &c.

as

as if the electric fluid, rushing from the positive side of the jar into the wire which communicated with it, and issuing from the extremity of it, was driven by its own impulse along the surface of the card, and did not pierce it, till it came opposite to the extremity of the other wire, which communicated with the negative side, by which it was strongly attracted *.

A VERY curious and elegant experiment on the Leyden phial was made by professor Richman of Petersburgh, whose unfortunate death will be related in this history.

HE coated both sides of a pane of glass, within two or three inches of the edge, and fastened linen threads to the upper part of the coating, on both sides; which, when the plate was not charged, hung down in contact with the coating; but setting the plate upright, and charging it, he observed, that when neither of the sides was touched by his finger, or any other conductor communicating with the earth, both the threads were repelled from the coating, and stood at an equal distance from it; but when he brought his finger, or any other conductor, to one of the sides, the thread hanging to that side fell nearer to the coating, while the thread on the opposite side receded as much; and that when his finger was brought into contact with one of the sides, the thread on that side fell into contact with it likewise, while the

* Dissertatio Physica, p. 24.

thread on the oppoſite ſide receded to twice the diſtance at which it hung originally; ſo that the two threads always hung ſo as to make the ſame angle with one another *.

ÆPINUS ſhows, that it is not ſtrictly true, that an inſulated perſon, diſcharging the Leyden phial through his own body, contracts no electricity. Electrifying a large plate of air, he obſerved, that if the nearer plate, (by which I ſuppoſe he means that which he firſt touched) was electrfiied poſitively, he acquired a poſitive electricity by the diſcharge; but if it were negative, he acquired a negative electricity. He ſuppoſes that the reaſon why the experiment did not ſucceed with Dr. Franklin, was, that the ſurfaces with which he tried the experiment were not large enough to make the effect ſenſible; and that the diſtance of the metal plates was, likewiſe, too ſmall, as it neceſſarily muſt be in charging of glaſs †.

MR. CIGNA has invented a new method of charging a phial, upon the principle diſcovered by Mr. Canton and Mr. Wilcke, viz. that the electricity of one body repels that of another, eſpecially if it have a flat ſurface, and gives it the contrary electricity.

HE inſulates a ſmooth plate of lead, and while he brings an electrified body, as a ſtocking, to it, he takes a ſpark with the wire of a phial from the oppoſite ſide; and removing the ſtocking, he takes another ſpark with

* Æpini Tentamen, p. 335. † Ibid. p. 27.

his

his finger, or any conductor communicating with the ground. Bringing the ſtocking nearer the plate a ſecond time, he takes a ſecond ſpark, with the wire of the phial, as before; and, removing it again, takes another, in the ſame manner, with his finger. This operation he continues, till the phial is charged; which, in favourable weather, may be done with very little diminution of the electricity of the ſtocking *.

If, inſtead of taking a ſecond ſpark with his finger, he had taken it with the wire of another phial, that would have been charged likewiſe, with no additional labour, and with an electricity oppoſite to that of the other phial. If the ſecond ſpark were taken with the coating of the ſame phial, the charging would be accelerated, but the operation would be troubleſome to manage.

The theory of this new method of charging a phial is very eaſy, upon the principle referred to above. The approach of the electricity in the ſtocking, not being able to enter the broad ſmooth ſurface of the metal, drives the electric fluid out of that part of the plate which is oppoſite to it, to the other ſide, which, being thereby overcharged, will part with its ſuperfluity to the wire of the phial. The ſtocking being taken away, the plate will have leſs than its natural ſhare of the electric fluid, and will therefore readily take

* Memoirs of the Academy at Turin for the year 1765, p. 49.

a ſpark, either from the finger, or the wire of another phial *.

THE ſame ingenious philoſopher makes a conſiderable difference between the electric fluid which gives the ſhock, and that on which ſome other phenomena of coated glaſs depend. The former, which is far the greateſt quantity, he ſuppoſes to reſide, either in the coating itſelf, or on the ſurface of the glaſs; whereas the other, he imagines, to have entered the pores, and affected the ſubſtance of the glaſs itſelf.

HE laid two plates of glaſs, well dried, one upon the other, as one piece; the lower of them being coated on the outſide; and, when they were inſulated, he alternately rubbed the uppermoſt plate with one hand, and took a ſpark from the coating of the lower with the other, till they were charged; when the coating, and both the plates adhered firmly together. Giving a coating to the other ſide, and making a communication between that and the other coating, the uſual exploſion was made. But the plates, though thus diſcharged, ſtill cohered; and though, while they were in this ſtate, they ſhowed no other ſign of electricity; yet, when they were ſeparated, they were each of them found to be poſſeſſed of an electricity oppoſite to that of the other.

IF the two plates were ſeparated before they were diſcharged, and the coating of

* Memoirs of the Academy at Turin for the year 1765, p. 51.

each

each were touched, a ſpark came from each; and when put together, they would cohere as before, but were incapacitated for giving a ſhock *.

He, therefore, compares the electricity which gives the ſhock to the electricity of the metal plate in the former experiment; which is loſt with taking one ſpark, as the ſilk is removed from it, and is different from the electricity by which the two plates of glaſs cohere. The one is diſperſed at once, but the other ſlowly; the one exiſting, as he ſuppoſes, in the conductors, or upon the ſurfaces of the electrics, and the other in the ſubſtance itſelf †.

Among experiments relating to the electric ſhock, we ought to mention what has been obſerved within this period of its amazing force in melting wires, and producing other ſurpriſing effects.

That even artificial electricity, ſays Dr. Watſon, in a paper read at the Royal Society June 28th, 1764, when in too great a quantity, and hurried on too faſt, through a fine iron wire, has a remarkable effect upon the wire, appears from a very curious experiment of Mr. Kinnerſley. This gentleman, in the preſence of Dr. Franklin, made a large caſe of bottles explode at once through a fine iron wire. The wire at firſt appeared red hot, and then fell into drops, which burned

* Memoirs of the Academy at Turin for the year 1765, p. 55. † Ibid. p. 56.

themſelves into the ſurface of his table or floor. Theſe drops cooled in a ſpherical figure like very ſmall ſhot, of which Dr. Franklin tranſmitted ſome to Mr. Canton, who repeated the experiment. This proves the fuſion to have been very complete; as nothing leſs than the moſt perfect fluidity could give this figure to melted iron.

MR. CANTON, in a note ſubſcribed to the ſame paper, obſerves, that the diameter of a piece of Mr. Kinnerſley's wire, which he received from Dr. Franklin, was one part in 182 of an inch. He adds, that artificial lightning, from a caſe of thirty-five bottles, would entirely deſtroy braſs wire, of one part in 330 of an inch. At the time of the ſtroke, he ſays, a great number of ſparks, like thoſe from a flint and ſteel, would fly upwards, and laterally, from the place where the wire was laid, and loſe their light, in the day-time, at the diſtance of about two or three inches. After the exploſion, a mark appeared on the table, the whole length of the wire, and ſome very round particles of braſs were diſcovered by a magnifier near the mark, but no part of the wire itſelf could be found *.

SIGNIOR BECCARIA was able to melt ſmall ſlips of metal, without incloſing, or covering them with pieces of glaſs. But he thought that the ſame colour was impreſſed upon glaſs by all the metals; and imagined that this

*Phil. Tranſ. Vol. liv. p. 208.

circum-

circumſtance was a trace of the fundamental principles being the ſame in them all *.

MR. DALIBARD obſerved, that, when a large pane of glaſs diſcharged itſelf, the poliſh was taken off at the place of the diſcharge, and that the track it left behind it was uſually, as he expreſſes it, in the *zig zag* form. With the piece of glaſs with which he made theſe diſcharges he pierced 160 leaves of paper. It contained 1200 ſquare inches †.

MR. WILCKE ſays, that, if a ſmall piece of metal be hung in a ſmall ſilken ſtring, oppoſite to a part of a glaſs jar, made thin for the purpoſe; upon the ſpontaneous diſcharge through that place, the piece of metal will be driven off to the diſtance of five or ſix inches ‡.

MR. WINKLER fired the ſeeds of clubmoſs (lycopodium) by diſcharging a phial through a quantity of them. He alſo fired the *aurum fulminans* placed upon a piece of parchment, which was torn to pieces by the exploſion §.

BY the electric ſhock, Signior Beccaria could melt borax and glaſs. But the moſt remarkable of his experiments with the electric ſhock are thoſe by which he *revivified metals.* This he did by making the exploſion between two pieces of the calces. In this manner he

* Elettriciſmo artificiale, &c. p. 134, 135.

† Hiſtoire abrigée, p. 84.

‡ Remarks on Franklin's Letters, p. 266.

§ Phil. Tranſ. Vol. xxxviii. pt. ii. p. 773.

revivified ſeveral of the metals, and among others, zink. He even produced real quickſilver from cinnabar *. In this caſe of revivification, he always obſerved ſtreaks of black beyond the coloured metallic ſtains, owing, as he imagined, to the phlogiſton driven thither from the parts that were vitrified, when the other part revivified the calx †.

ANOTHER curious experiment he made with the electric ſhock, by diſcharging it through ſome braſs duſt, ſprinkled between two plates of ſealing-wax. The whole was perfectly luminous and tranſparent ‡. An experiment which throws ſome light upon one of Mr. Haukſbee's.

WITH the electric ſhock he alſo made that capital experiment, on which he lays ſo much ſtreſs in his theory of thunder ſtorms, and by which he proves, that the electric matter forces into its paſſage all light conducting ſubſtances; by means of which it is enabled to paſs through a quantity of reſiſting medium, which it could not otherwiſe do. He put a narrow piece of leaf ſilver between two plates of wax, laying it acroſs the plates, but ſo as not quite to reach one of the ſides. The diſcharge being made through this ſtrip of metal, by bringing a wire oppoſite to the ſilver, at the place where it was diſcontinued; the ſilver was found melted, and part of it diſperſed all along the track that the electric matter took, between the plates

* Lettere dell' elettriciſmo, p. 282. † Ibid. p. 255.
‡ Ibid. p. 257.

of

of wax, from the ſilver to the wire *. An accident gave him occaſion to obſerve another fact of a ſimilar nature. He once, inadvertently, received the charge of a ſmall jar, through ſome ſmoke of ſpirit of nitre; when a hole was made in his thumb, where the fire entered; and which he thought could only have been made by the nitre, which was carried along with the electric fluid †.

VIOLENTLY as the electric exploſion generally affects the human body, we have accounts of ſome perſons who could not be made to feel it; particularly three or four mentioned by Mr. Muſchenbroeck, among whom was a young woman ‡. I have alſo been told, that this was the caſe with a perſon near Leeds, who was at the ſame time a little paralytic.

I SHALL cloſe the hiſtory of the Leyden phial for this period with the accounts of ſome extremely curious facts, which Mr. Canton gives me leave to publiſh relating to this ſubject. They certainly deſerve the utmoſt attention of philoſophers, and may probably throw ſome light upon the electricity of the tourmalin.

HE procured ſome thin glaſs balls, of about an inch and a half in diameter, with ſtems or tubes of eight or nine inches in length, and electrified them, ſome poſitively on the inſide, and others negatively, after the manner of charging the Leyden phial,

* Lettere dell' elettriciſmo, p. 248. † Ibid. p. 249.
‡ Monthly Review, October 1767, p. 250.

and

and then sealed them hermetically. Soon after, he applied the naked balls to his electrometer, and could not discover the least sign of their being electrical: but holding them to the fire, at the distance of five or six inches, they became strongly electrical, in a very short time, and more so when they were cooling. These balls would, every time they were heated, give the electric fire to, or take it from other bodies, according to the *plus* or *minus* state of it within them. Heating them frequently, he found, would sensibly diminish their power; but keeping one of them under water a week did not appear in the least to impair it. That which he kept under water was charged the 22d of September 1760, was several times heated before it was kept in water, and had been heated frequently afterwards; and yet it still retained its virtue to a considerable degree, on the 31st of October following, when he sent an account of it to Dr. Franklin. The breaking two of his balls accidentally gave him an opportunity of measuring their thickness, which he found to be between seven and eight parts in 1000 of an inch.

THE balls mention in the account above, which was written six years ago, still * retain their virtue, but in a less degree.

MR. LULLIN also found, that a glass tube charged, and hermetically sealed, would show signs of electricity when it was heated †.

* In 1769. † Dissertatio Physica, p. 32.

SEC-

SECTION VIII.

EXPERIMENTS AND OBSERVATIONS CONCERING ELECTRIC LIGHT.

MY reader has been informed of the neceſſity I was under of dividing the buſineſs of this period of my hiſtory into ſeveral parts. He has already ſeen titles which he could not have expected from the diviſions of the preceding periods, but he would perhaps leaſt of all expect a diſtinct ſection upon electric light; and yet the experiments and obſervations which have been made, immediately relating to this ſubject, are ſo many, that they deſerve a place by themſelves. And I would rather err by making too many ſubdiviſions, than too few; becauſe, above all things, I would wiſh to preſerve perſpicuity, which is chiefly injured by crowding together things diſſimilar.

MANY experiments had been made very early, by Mr. Haukſbee and others, on electricity, and particularly electric light, in vacuo; but ſo little was, at that time, known of the nature of electricity in general, that, comparatively, little uſe could be made of thoſe experiments. Very fortunately, Dr. Watſon happened to turn his thoughts that way, after the great diſcovery of the accumulation of electricity in the Leyden phial; and by this means he diſcovered, that our atmoſphere, when

when dry, is the agent by which, with the aſſiſtance of other electrics per ſe, we were enabled to accumulate electricity upon non-electrics (he might have added electrics too), that is, to communicate to them a greater quantity of electricity than thoſe bodies naturally have. That upon the removal of the air, the electric fluid pervaded the vacuum to a conſiderable diſtance, and manifeſted its effects upon any non-electric ſubſtances by which it was terminated.

THIS he demonſtrated by one of the moſt beautiful experiments which the whole compaſs of electricity yet exhibits. He exhauſted a glaſs cylinder, three feet in length, and three inches in diameter, with a contrivance to let down a braſs plate, as far as he pleaſed, into it; in order to make it approach another plate, fixed near the bottom of the veſſel.

THIS cylinder, thus prepared, he inſulated, and obſerved, that when the upper plate was electrified, the electric matter would paſs from one plate to another, at the greateſt diſtance to which the braſs plates could be drawn; and that the braſs plate at the bottom of the cylinder was ſtrongly electrified, as if a wire had connected it with the prime conductor. It was a moſt delightful ſpectacle, he ſays, when the room was darkened, to ſee the electric matter in its paſſage through this vacuum; to obſerve, not as in the open air, ſmall bruſhes or pencils of rays, an inch or two in length, but coruſcations of the whole length

of

of the tube, and of a bright ſilver hue. Theſe did not immediately diverge, as in the open air, but frequently, from a baſe apparently flat, divided themſelves into leſs and leſs ramifications, and reſembled very much the moſt lively coruſcations of the aurora borealis.

Sometimes he obſerved, that when the tube had been exhauſted in the moſt perfect manner, the electric fluid was ſeen to paſs between the braſs plates in one continued ſtream, of the ſame dimenſions throughout its whole length; which he thought demonſtrated, that the cauſe of that very powerful mutual repulſion of the particles of electric fire, which is ſeen in the open air, is more owing to the reſiſtance of the air, than to any natural tendency of the electricity itſelf. For, in the open air we obſerve that theſe bruſhes, when the electricity is ſtrong, diverge ſo much, as to form almoſt a ſpherical figure *.

He made this vacuum part of a circuit neceſſary to make the diſcharge of a phial; and, at the inſtant of the exploſion, there was ſeen a maſs of very bright embodied fire, jumping from one of the braſs plates in the tube to the other. But this did not take place when one of the plates was farther diſtant from the other than ten inches. If the diſtance was greater, the fire began to diverge, and loſe part of its force: and this force diminiſhed in proportion to its divergency,

* Phil. Tranſ. Vol. xlvii. p. 367.

which was nearly as the diſtance of the two plates.

To find a more perfect vacuum for the paſſage of the electric fluid, he had recourſe to an excellent invention of Lord Charles Cavendiſh; who, by means of a long bent tube of glaſs, filled with mercury, and inverted, made all the bended part of it (which was above the mercury) the moſt perfect vacuum that can be made. This vacuum Dr. Watſon inſulated, and one of the baſons of the mercury being made to communicate with the conductor, when ſome non-electric ſubſtance touched the other, the electric matter pervaded the vacuum in a continued arch of lambent flame, and, as far as the eye could follow it, without the leaſt divergency.

CONNECTING one of the baſons with the machine, which was inſulated, the fire was ſeen pervading the vacuum in a contrary direction. And this he conſidered as the *experimentum crucis* of two principles which he had advanced before, viz. that electricity is furniſhed to the conductor, not by the excited electric, but from the non-electrics in contact with the rubber; and that we are able to take from, or add to that quantity of electricity, which is naturally inherent in bodies.

HE alſo obſerved, that if, in the forementioned circumſtances, the hand of a perſon ſtanding upon the floor was brought near the ſide of the glaſs, the coruſcations would dart themſelves that way in a great variety of forms, extremely curious to behold.

BUT

But the Doctor found, that even this vacuum did not conduct ſo perfectly as metals, or water; becauſe a perſon ſtanding upon the floor, and applying his finger to the upper braſs plate, received a ſmart ſtroke. This he conceived to ariſe from the electricity of the braſs being ſo much more rarefied than that of the body of the man who applied his finger *.

Mr. Wilson engaged Mr. Smeaton, the inventor of a new and more perfect kind of air-pump, to make ſome electrical experiments in vacuo. The following is the account of them that he tranſmitted to Mr. Wilſon. They are, in ſeveral reſpects, ſimilar to thoſe made by Dr. Watſon, and yet are attended with a conſiderable variety of new circumſtances.

A glass veſſel, about one foot in length, and eight inches in its greateſt diameter, open at both ends, had one of its ends cloſed by a braſs ferule, which conſtituted one of the centers on which it turned; the other end was cloſed with a metal plate. In the center of this plate was a ſquare ſtem, which was applied to the arbor of a lath, by which the glaſs was turned round. On one ſide of this laſt plate was fixed a cork, by means of which the glaſs was ſcrewed upon the air-pump.

Upon rarefying the air within the glaſs about 500 times, and afterwards turning the

* Phil. Tranſ. Vol. xlvii. p. 373.

glaſs

glaſs in the lath, whilſt, at the ſame time, it was rubbed with his hand; a conſiderable quantity of lambent flame, variegated with all the colours of the rainbow, appeared within the glaſs, under the hand. This light was pretty ſteady in every reſpect, except that every part of it was perpetually changing colour.

WHEN a little air was let into the glaſs, the light appeared more vivid, and in a greater quantity, but was not ſo ſteady: for it would frequently break out into a kind of coruſcations, like lightning, and fly all about within the glaſs. When a little more air was let in, the flaſhing was continual, and ſtreams of blueiſh light ſeemed to iſſue from under his hand, within the glaſs, in a thouſand forms, with great rapidity; and appeared like a caſcade of fire. Sometimes it ſeemed to ſhoot out into the forms of trees, moſs, &c.

WHEN more air was let in, the quantity of light was diminiſhed, and the ſtreams compoſing the flaſhes narrower. The glaſs now required a greater velocity, and harder friction. Theſe circumſtances increaſed as more air was let in; ſo that, by ſuch time as the glaſs was one third full of air, theſe coruſcations quite vaniſhed, and a much ſmaller quantity of light appeared partly within, and partly without the glaſs. And when all the air was let in, the light appeared wholly without the glaſs, and much leſs in quantity than when the glaſs was in part exhauſted *.

* Wilſon's Eſſay, p. 216.

MR.

Mr. Canton, in repeating Dr. Watſon's experiment with the Torricellian vacuum, obſerved one circumſtance attending it, which throws great light upon the Leyden phial. He obſerved, that when the excited tube was brought near one of the baſons of this machine (inſulated) a light was ſeen through more than half of the vacuum; which ſoon vaniſhed, if the tube was not brought nearer, but which appeared again as it moved farther off; and that this appearance might be repeated ſeveral times, without exciting the tube afreſh.

This experiment he conſidered as a kind of ocular demonſtration of the truth of Dr. Franklin's hypotheſis, that when the electric fluid was condenſed on one ſide of the glaſs, it was repelled from the other, if it met with no reſiſtance. Thus, at the approach of the excited tube, he ſuppoſed the fire to be repelled from the inſide of the glaſs ſurrounding the vacuum, and to be carried off through the columns of mercury, but to return again as the tube was withdrawn *.

This curious experiment Mr. Canton, as he informed me, ſhowed and explained to Mr. Wilſon; who afterwards expatiated upon it, in a book publiſhed by him and Dr. Hoadley in conjunction, intitled *Obſervations*

* Phil. Tranſ. Vol. xlviii. pt. i. p. 356. It has been ſeen p. 95, that this obſervation, of the return of the electric light *in vacuo*, was made before the diſcovery of the Leyden phial by Mr Grummert of Biala in Poland; but this was unknown both to Dr. Watſon and Mr. Canton.

on a Series of Electrical Experiments; in a note of which, p. 28, he ſays, "Mr. Canton has taken notice of this vaniſhing and "returning of the light."

MR. CANTON has ſince diverſified this beautiful experiment, by bringing the excited tube to another glaſs tube, exhauſted, and hermetically ſealed; by which means he exhibits the perfect appearance of an aurora borealis. The flame from one of its extremities, which is in a manner coated by the hand which holds it, will dart to the other extremity, at uncertain intervals of time, for near a quarter of an hour together, without repeating the application of the excited tube.

WHEN it was generally agreed among electricians, that what had been called vitreous and reſinous electricity were in reality a redundancy of the electric fluid in one caſe, and a deficiency in the other; and when, in conſequence of this ſuppoſition, the one was called poſitive, and the other negative electricity; there ſtill remained ſome doubt which of the two was poſitive, and which negative. Mr. Wilſon, in a paper read at the Royal Society, December the 6th, 1759, recites an experiment which, he thought, put the matter beyond all diſpute, and abſolutely determined, that what had been called vitreous was really poſitive, and what had been called reſinous was negative; as, indeed, had generally been ſuppoſed, though, as Mr. Wilſon thought, without ſufficient reaſon, notwithſtanding what had been advanced by Dr. Franklin,

Franklin, and Mr. Canton upon that subject.

REPEATING the beautiful experiment mentioned before, as first contrived by Lord Charles Cavendish, he says he attended to a circumstance which seemed to have been overlooked by Dr. Watson, who published the account of it. This was a singular appearance of light upon one of the surfaces of the quicksilver. To observe this remarkable appearance to more advantage, Mr. Wilson let a small quantity of air into the tube, by which means four columns of quicksilver were obtained, and consequently six visible surfaces, in one of the legs of the inverted tube. He then electrified the mercury in the other leg, while the mercury on the opposite side had a communication with the earth, when, the room being dark, the stream of electric light was visible through the whole length of the vacuum, and its general appearance was of a seeming uniform density; except at the upper surfaces of each column, where about one tenth of an inch above the surface, the light was always considerably brighter; whereas the under surfaces exhibited no such appearance, the light being rather less bright in those places than in the general appearance of the whole illuminated vacuum.

THIS luminous appearance Mr. Wilson ascribed to the resistance the fluid met with at the upper surface of the quicksilver, in endeavouring to get into it. He therefore inferred that excited glass electrified bodies po-

 sitively,

ſitively, or gave them a greater quantity of the electric fluid than they had.

ELECTRIFYING, in the ſame place, with a cylinder of roſin, inſtead of glaſs, the luminous appearances were all on the under ſurfaces of the columns of quickſilver; from which he inferred, that roſin electrified bodies negatively, depriving them of part of the electric fluid which they naturally had; or, as he expreſſes it, occaſioning a current of electric fluid to ſet the contrary way.

THESE luminous appearances, Mr. Wilſon alſo conſidered, as a ſtrong confirmation of the exiſtence of a *medium*, at or near the ſurfaces of bodies, which hindered the entrance or exit of the electric fluid. A doctrine which Mr. Wilſon had advanced, and laid great ſtreſs upon on ſeveral other occaſions *.

THE arguments which to Mr. Wilſon appeared concluſive, in proof of what is commonly ſuppoſed, that glaſs electrifies *plus*, and ſulphur, &c. *minus*, did not appear ſo to Mr. Æpinus; though he acknowledges that the knobs of light in the vacuum did, in common with many other appearances, prove a real difference between the two electricities; and thought that it was very eaſy to conceive, that when an elaſtic fluid iſſues from a body, it ſhould be denſer near the ſurface from whence it iſſues, than where it finds more liberty to expand itſelf. He might have added, that this might have been expected, from

* Phil. Tranſ. Vol. li. pt. i. p. 308.

the

the mutual attraction which is ſuppoſed to ſubſiſt between the electric fluid, and other bodies. But Æpinus did not expreſsly mention this circumſtance. Mr. Wilſon, therefore, makes light of the objection; and adds, that when he related the experiment with the bent tube, in his letter to Dr. Heberden, he omitted ſome phenomena attending the fact, which greatly favoured the doctrine he advanced. If, ſays he, when glaſs is electrified, and applied to the firſt column, we ſuffer the electric fluid to paſs along the tube in ſmall quantities only, and at ſhort intervals, little luminous ſtreams will be ſeen to move from the firſt to the ſecond column of quickſilver, and conſequently from the glaſs. The like appearances happen, but in a contrary direction, when roſin or amber is made uſe of, and applied to the ſame column. Glaſs, therefore, he concludes, electrifies *plus*, or fills bodies with more of this fluid than belongs to them naturally, and roſin, &c. *minus* *.

This controverſy took its riſe, in ſome meaſure, from a deception: for Mr. Canton informs me, and gives me leave to inform the public, that the light which Mr. Wilſon takes notice of, as appearing on one ſurface of the mercury in the double barometer of Lord Charles Cavendiſh, and which Mr. Wilſon takes to be a proof of the exiſtence of a medium on the ſurface of bodies, which hinders the entrance or exit of the electric fluid to

* Phil. Tranſ. Vol. liii. p. 438. p. 441.

ſome degree, he found to be cauſed by nothing but common air. For if the Torricellian vacuum be properly made, no difference of light can be ſeen on the ſurfaces of the columns of mercury; but if as much air be let into the vacuum, as will make each column of mercury a quarter of an inch ſhorter than that of a good barometer, the light will appear as Mr. Wilſon has deſcribed it. When Mr. Wilſon ſuppoſed that Dr. Watſon, when he made the experiment of the Torricellian vacuum, did not attend to the ſingular appearance of light on one of the ſurfaces of the mercury, he little ſuſpected that if the vacuum Dr. Watſon made was free from air, there was no ſuch ſingular appearance of light to be attended to. Air, Mr. Canton adds, muſt be condenſed near the ſurface of all bodies that attract it; and will, therefore, be ſome hindrance to the exit, or entrance of the electric fluid, except the bodies be very ſharply pointed.

SOME curious obſervations relating to electric light were made by Mr. Wilcke. Rubbing two pieces of glaſs together in the dark, he obſerved a vivid phoſphoreal light: which, however, threw out no rays, but adhered to the place where it was excited. It was attended with a ſtrong phoſphoreal ſmell, but with no attraction or repulſion. From this experiment he inferred, that friction alone would not excite electricity, ſo as to be accumulated upon any body; and that to produce this effect, the bodies rubbed together

muſt be of different natures, with reſpect to their attracting the electric fluid. He, moreover, imagined, that all examples of phoſphoreal light, without attraction, were owing to the ſame excitation of electricity, without the accumulation of it. Such he imagined to be the caſe of light emitted by the Bolognian ſtone, cadmea fornacum, rotten wood, pounded ſugar, and glaſs of all kinds *.

A TUBE excited with a woollen cloth, on which white wax or oil had been put, he ſays, threw out flames; each of which when examined, appeared to riſe out of a little protuberance of fire. The flame was one, and very narrow at the bottom, but farther from the tube it divided into ſeveral ramifications; which always leaned to thoſe parts of the tube which were the leaſt excited, or to conductors in the neighbourhood †.

HE ſays that, upon preſenting a finger or other non-electric to an excited negative electric, a cone of light is formed; the baſe of which is at the finger, or other non-electric, and the apex at the electric, on the ſurface of which it ſpreads to a conſiderable diſtance all round ‡.

SOMETIMES, he had ſeen fiery particles thrown laterally from an irregular electric ſpark, which ſhone like ſtars, and were very like thoſe which are produced by the colliſion of flint and ſteel §.

* Wilcke, p. 123, 124.
† Ibid. p. 125.
‡ Ibid. p. 127.
§ Ibid. p. 130.

SUSPENDING various balls from his conductor, and presenting others to them, which were ſometimes of glaſs and ſometimes of metal, and varying them in every manner poſſible, he always found (except when two metal balls were uſed) that the light between them formed a cone, the baſe of which was always on the body which was poſitive, and the apex on that which was negative. He ſays that this criterion is ſufficient to diſtinguiſh the two electricities from one another.

HE obſerves that, at the apex of a cone iſſuing from pointed bodies, electrified poſitively, there is a cylindrical ſpark, out of which lucid rays, like a river, are darted. Theſe rays, he ſays, form a lucid cone, the apex of which is turned towards the point from which the fire proceeds. Sometimes from the apex, or at ſome diſtance from it, there is a lucid point, which, he ſays, Hauſenius calls *the fire of the ſecond kind*, out of which flew ſtreams of fire. The ſtreams never iſſue from the electrified body itſelf, but always from this lucid point. He ſays, moreover, that this lucid point at the extremity of an electrified body, and which throws out lucid rays, forms the diſtinctive character of the poſitive cone *.

A NEGATIVE cone, he ſays, is ſmall, conſiſting of very ſlender filaments, which immediately adhere to the point at which the light

* Wilcke, p. 132.

enters,

enters, or to its fides; and, if accurately examined, feems to form little cones, the bafes of which reft upon the body.

WHEN he afterwards comes to confider the caufe of negative cones of light, he owns himfelf to be at a great lofs how to do it.

MR. WILCKE put Englifh phofphorus upon a pointed body, which, in the dark, rendered the whole vifible; and when he fufpended this pointed body perpendicularly, the phofphoreal vapours were feen to afcend; but upon electrifying it, as it hung in the fame direction, the vapours were carried downwards, and formed a very long cone, extending out of the middle of the cone of electric light, which was feen perfectly diftinct from it. When the electrification was difcontinued, the phofphoreal vapour afcended as at firft. From this depreffion of the phofphoreal effluvia Mr. Wilcke infers the efflux of the electric fluid from the point, and upon the furface, and not only through the fubftance of the pointed body. It is pity that he did not try this curious experiment with pointed bodies electrified negatively. He would certainly have found the fame depreffion of the phofphoreal effluvia, and would, probably, have retracted his conclufion concerning this proof of the efflux *.

MR. WILCKE alfo thought it to be a proof, that the electric matter did not only flow out of the fubftance of electrified bodies, but up-

* Wilcke, p. 134.

on

on the ſurface of them, that a metallic ring, projecting ever ſo little beyond the point of a wire on which it had been put, prevents the appearance of the lucid point.

THE laſt obſervation which I ſhall recite of Mr. Wilcke concerning electric light is, that if a point not electrified be oppoſed to a point electrified poſitively, the cones of light, which, in other circumſtances, would appear upon both of them, diſappear; but that if a poſitive cone be oppoſed to a negative cone, they both preſerve their own characteriſtic properties *.

SIGNIOR BECCARIA was of opinion, that the direction of the electric fluid may be determined from the phenomena of pointed bodies. The *pencil* (by which he means the electric fire at a point electrified poſitively) he ſays, contracts as it approaches a flat piece of metal not electrified; whereas the *ſtar* (by which he means the electric fire at a point electrified negatively) expands in the ſame circumſtances, and has a ſmall cavity near the point towards the large ſuperficies. The pencil is attended with a ſnapping noiſe, the ſtar makes little or no noiſe. He hardly gives any reaſon for the firſt of theſe phenomena; he only ſays, that ſuch is the neceſſary conſequence of a fluid iſſuing out of, or entering into a point. But the greater noiſe made by the pencil, he thought was made by the impulſe given by the electric matter to the air,

* Wilcke, p. 140.

causing

causing it to vibrate: and this must be greater when the fluid is thrown from the point into the air, than when it comes through different portions of the air, and meets in one point *.

When two points are opposed to one another, he says, the phenomena are much the same in both †.

Signior Beccaria observed that hollow glass vessels, of a certain thinness, exhausted of air, gave a light when they were broken in the dark. By a beautiful train of experiments, he found, at length, that the luminous appearance was not occasioned by the breaking of the glass, but by the dashing of the external air against the inside, when it was broke. He covered one of these exhausted vessels with a receiver, and letting the air suddenly on the outside of it, observed the very same light. This he calls his *new invented phosphorus* ‡.

This excellent philosopher produced a most beautiful appearance of electric light in the following manner. He conveyed positive electricity to a brass ball, suspended by a wire, within an exhausted receiver, when, upon presenting to it another ball *in vacuo*, the lower hemisphere of the former was most beautifully illuminated, with a visible electric atmosphere. When he conveyed negative electricity to the ball, the same beautiful illumination was observed on the ball presented to it. This experiment, he says, is a very deli-

* Elettricismo artificiale, p. 63. † Ibid.
‡ Lettere dell' ellettricismo, p. 365, &c.

cate

cate one, requiring great patience and dexterity, in adjusting the distances, &c. in order to make it succeed perfectly *.

That electric light is more subtle and penetrating, if one may say so, than light produced in any other way is manifest from several experiments, particularly the remarkable one of Mr. Hauksbee; but none prove it so clearly as some made by the ingenious Mr. Lane, who gives me leave to mention these.

When he had, for some different purpose, made the electric shock pass over the surface of a piece of marble, in the dark; he observed, that the part over which the fire had passed was luminous, and retained that appearance for some time. No such effect of the electric shock having ever been observed before, he repeated the experiment with a great variety of circumstances, and found it always answered with all calcarious substances, whether animal or mineral, and especially if they had been burnt into lime. And, as far as he had tried, many more substances would retain this light than would not do it; among others several vegetable substances would do it, particularly white paper. Tiles and brick were luminous, but not tobacco-pipe clay, though well burnt.

That gypseous substances, when calcined, were luminous, appeared from bits of

* Phil. Transf. Vol. lvi. p. 107.

images made of plaiſter of Paris; and of this claſs, he ſays, is the famous Bolognian ſtone. But many bodies, he found, were luminous after the electric ſtroke, which were not apparently ſo, when expoſed to the rays of the ſun.

He made theſe curious experiments by placing the chains, or wires that led from the conductor to the outward coating of his jar, within one, two, or three inches (according to the ſtrength of the charge) from one another, on the ſurface of the body to be tried, and diſcharging a ſhock through them. If the ſtone was thin, he found, that if one chain was placed at the top, and the other at the bottom, it would appear luminous on both ſides after the exploſion.

Mr. Canton, to whom theſe experiments were communicated, clearly proved, that it was the *light* only that the ſubſtances retained, and nothing peculiar to electricity; and, moreover, after frequent trials, diſcovered a compoſition, which retains both common light, and that of electricity, much more ſtrongly than either the Bolognian ſtone, or any other known ſubſtance whatever. With this new phoſphorus he makes a great number of moſt beautiful experiments. The flaſh made by the diſcharge of a common jar, within an inch of a circular piece of it, of about two inches and a half in diameter, will illuminate it ſo much, that the figures on a watch plate may be eaſily diſtinguiſhed by it in

in a darkened room; and it will retain the light half an hour *.

I SHALL close this section of experiments and observations on electric light, with an account of a remarkable appearance which occurred to Mr. Hartman. When he had been making experiments four or five hours together, in a small room, and after going out of it, returned soon, with a lighted candle in his hand, walking pretty swiftly; he perceived a small flame to follow him, at the distance of about a step and a half, but it vanished when he stopped to examine it. He was a good deal alarmed at the appearance at first, but afterwards imagined it to be occasioned by the ascension of the sulphur, which had been thrown into the air by the violent continued electrification †.

* See a particular account of this composition, and experiments with it, in my *History of Discoveries relating to Vision, Light, and Colours*, p. 371.

† Abhandlung, p. 135.

SECTION

SECTION IX.

THE ELECTRICITY OF THE TOURMALIN.

THIS period of my hiſtory furniſhes an entirely new ſubject of electrical inquiries; which, if properly purſued, may throw great light upon the moſt general properties of electricity. This is the *Tourmalin*: though, it muſt be acknowledged, the experiments which have hitherto been made upon this foſſil ſtand like exceptions to all that was before known of the ſubject.

THE tourmalin, as Dr. Watſon ſuppoſes, was known to the antients under the name of the *lyncurium*. All that Theophraſtus ſays concerning the lyncurium agrees with the tourmalin, and with no other foſſil that we are acquainted with. He ſays, that it was uſed for ſeals, that it was very hard, that it was endued with an attracting power like amber, and that it was ſaid, particularly by Diocles, to attract not only ſtraws, and ſmall pieces of wood, but alſo copper and iron, if beaten very thin; that it was pellucid, of a deep red colour, and required no ſmall labour to poliſh it. The account which paſſed current among the ancients concerning the origin of this ſtone was fabulous, which made Pliny think that all that was ſaid of it was fabulous too.

THIS

This ſtone, though not much attended to by European philoſophers, till very lately, is common in ſeveral parts of the Eaſt Indies, and more particularly in the iſland of Ceylon, where it is called by the natives *tournamal*. In this iſland the Dutch became acquainted with it, and by them it is called *aſchentrikker*, from its property of attracting aſhes, when it is thrown into the fire.

The firſt account we have had, of late years, concerning this extraordinary ſtone is in the Hiſtory of the Royal Academy of Sciences at Paris for the year 1717; where we are told, that Mr. Lemery exhibited a ſtone, which was not common, and came from Ceylon. This ſtone, he ſaid, attracted and repelled ſmall light bodies, ſuch as aſhes, filings of iron, bits of paper, &c.

Linnæus, in his Flora Zeylonica, mentions this ſtone under the name of *lapis electricus*, and takes notice of Mr. Lemery's experiments.

Notwithstanding this, no farther mention was made of this ſtone and its effects till ſome years after; when the Duc De Noya, in his letter to Mr. Buffon, preſented to the Royal Society, informed us, that when he was at Naples, in the year 1743, the Count Pichetti, ſecretary to the king, aſſured him, that, during his ſtay at Conſtantinople, he had ſeen a ſmall ſtone called *tourmalin*, which attracted and repelled aſhes. This account the Duc De Noya had quite forgotten, but being in.

in Holland in the year 1758, he ſaw, and purchaſed two of thoſe ſtones. With theſe, in company with Meſſrs. Daubenton and Adamſon, he made a great number of experiments, of which he favoured the public with a particular account *.

But prior to the Duc De Noya's experiments, Mr. Lechman had acquainted Mr. Æpinus with the attractive power of the tourmalin, and furniſhed him with two of them, on which he made many experiments; the reſult of which he publiſhed in the Hiſtory of the Academy of Sciences and Belles Lettres at Berlin for the year 1756. The ſubſtance of the memoir is as follows.

The tourmalin has always, at the ſame time, a poſitive and a negative electricity; one of its ſides being in one ſtate, and the other in the oppoſite; and this does not depend on the external form of the ſtone. Theſe electricities he could excite in the ſtrongeſt degree, by plunging the ſtone in boiling-water.

If one ſide of the tourmalin be heated more than the other (as if it be laid upon a hot cake of metal) each of the ſides acquire an electricity oppoſite to that which is natural to it; but if left to itſelf, it will return to its natural ſtate.

If one of the ſides of the tourmalin be rubbed, while the other is in contact with ſome conductor communicating with the ground;

* Phil. Tranſ. Vol. li pt. i. p. 396.

the rubbed side is always positive, and the other negative. If neither side be in contact with a conductor, both become positive. If, in the former of these cases, the tourmalin be rubbed, so as to acquire a sensible heat, and the side which is naturally positive be made negative, it will upon standing to cool, return to its natural state; but if it have acquired no sensible heat, it will not return to its natural state while any kind of electricity remains. If it be heated, even when it is rubbed and insulated, (in which case both sides become positive) it will still return to its natural state upon cooling.

The Duc De Noya mentions these experiments of Mr. Æpinus, but does not admit of a *plus* and *minus* electricity belonging to the tourmalin when heated. On the contrary, he says, that both the sides are electrified *plus*, but one of them more than the other, and that it was the difference between those degrees which led Mr. Æpinus into his mistake *.

The tourmalin was introduced to the notice of the English philosophers by Dr. Heberden, who fortunately recollecting to have seen one of them, many years before, in the possession of Dr. Sharp at Cambridge (and it was the only one known in England at that time) procured it for Mr. Wilson; who, though it was but a small one, repeated with it most of the experiments of Mr. Æpinus, so far as to

* Phil. Transf. Vol. lvii. pt. i. p. 315.

satisfy

ſatisfy himſelf that his opinion of its poſitive and negative power was well founded.

Afterwards, Dr. Heberden, ever deſirous of extending the bounds of ſcience, procured ſome of theſe ſtones from Holland, and put them into the hands of thoſe perſons who were likely to make the beſt uſe of them, particularly Mr. Wilſon and Mr. Canton; in whoſe hands they were not lodged in vain, as will appear by the brief account I ſhall ſubjoin of their experiments upon them.

Mr. Wilson's obſervations are too many, and too particular to be all inſerted in this work. The reſult of them was, in the main, the ſame with that of Mr. Æpinus, eſtabliſhing the opinion of the two different powers of this ſtone; but, contrary to Mr. Æpinus, he aſſerts, that when the ſides of the tourmalin are unequally heated, it exhibits that ſpecies of electricity which is natural to the hotter ſide, that is, the tourmalin is *plus* on both ſides, when the *plus* ſide is the hotter; and *minus* on both ſides, when the *minus* ſide is the hotter.

Upon this Mr. Æpinus repeated all his former experiments, and ſtill found the reſult of them agreeable to his former concluſion, and contrary to that of Mr. Wilſon. Mr. Wilſon alſo repeated his, without any variation in the event, and imagined the difference between him and Mr. Æpinus might ariſe from the different ſizes of the tourmalins they made uſe of, or from their different manner of making the experiments. And it is evident, from

the deſcription of both their apparatuſes, that of Mr. Wilſon was much better calculated for the purpoſe of accurate experiments than that of Mr. Æpinus. Mr. Wilſon alſo uſed a greater variety of methods of communicating heat to his tourmalins. He both plunged them in boiling water, held them to the flame of a candle, and expoſed them to heated inſulated electrics *.

THOUGH the detail of all Mr. Wilſon's experiments would be, as I obſerved before, much too long for my purpoſe, I cannot help relating one of them, which was made with the laſt mentioned method of treating. He heated one end of a glaſs tube red-hot, and when he had expoſed what both he and Mr. Æpinus call the negative ſide of the tourmalin to it; he obſerved that about three inches of the heated part of the glaſs were electrified *minus*, though the glaſs beyond that was electrified *plus*, and continued ſo even after the glaſs was cold, the electric fluid having paſſed from the tourmalin to the glaſs; ſince theſe were the ſame appearances that were produced by preſenting an excited tube to the heated glaſs.

HE then applied the *plus* ſide of the tourmalin to the ſame heated glaſs, and found that the tube was electrified *minus*, above a foot in length, without the leaſt appearance of a *plus* electricity beyond the *minus* one, as in the other experiment; and this *minus* electricity

* Phil. Tranſ. Vol. liii. p. 436, &c.

appeared

appeared when the tube was nearly cold. In this case he judged that the electric fluid had passed from the glass to the tourmalin.

Mr. Wilson imagined that the tourmalin, as well as glass, was permeable to the electric fluid, and that the resistance to its entering the substance of it was less on what he calls the negative than on the positive side. These conclusions he drew from the two following experiments. Rubbing the positive side of the stone slightly, he found both sides electrified *plus*, but rubbing the negative side in the same manner, both sides were electrified *plus* more strongly than before *.

Several experiments led Mr. Wilson to conclude that the tourmalin resisted the exit and entrance of the electric fluid considerably less than glass, or even than amber; and upon the whole he infers, that the tourmalin differs in nothing from other electric bodies but in acquiring electricity by heat †.

Examining a great number of tourmalins, he found that a line drawn from the *plus* part, through the center of the stone, would always pass through the *minus* part.

Almost all these tourmalins he greased over, and whilst they were warm enough to preserve the grease liquid, he tried each tourmalin separately, but found no alteration in the virtue of the stone, except that it was a little weakened; though it is well known, he says, that moisture of any sort readily conducts

* Phil. Transf. Vol. li. pt. i. p. 327. † Ibid. p. 329.

the electric fluid. If, therefore, the tourmalin had not a fixed kind of electricity, the *plus* and *minus* electricity, observable on the two sides of the stone, must, by this treatment, have united and destroyed each other. From this circumstance Mr. Wilson concluded, that the tourmalin suffered the electric fluid to pass through it only in one direction, and that in this it bore some analogy to the loadstone; having, as it were, two electric poles, which are not easily destroyed or altered *. But he was not aware how imperfect a conductor oil or grease of any kind is.

THIS induced him to try whether, like the loadstone, the tourmalin would lose its virtue after being made red-hot; but, though he kept two of them in a strong fire for half an hour, he could not perceive the least alteration in them: but plunging one in water, while it was red-hot entirely destroyed its virtue, and gave it the appearance of having been shivered in many parts without breaking †. He observes that when a tourmalin, which he had from Dr. Morton, was held between the eye and the light, and viewed in the direction through which the electric fluid is found to pass, it appears of a darker colour considerable than when it is viewed at right angles to the former direction. This appearance, he says, obtains in many other tourmalins, especially when they happen to be as conveniently shaped ‡.

* Phil. Tranf. Vol. li. pt. i. p. 337, 338.
† Ibid. p. 338 ‡ Ibid. Vol. liii. p. 448.

NOT-

NOTWITHSTANDING the attention given to this ſubject by Mr. Æpinus and Mr. Wilſon, the moſt important diſcovery relating to the electricity of the tourmalin was reſerved for Mr. Canton; who, in a paper read at the Royal Society in the ſame month with that above-mentioned of Mr. Wilſon, viz. December 1759, obſerves, that the tourmalin emits and abſorbs the electric fluid only by the increaſe or diminution of its heat. For if the tourmalin, he ſays, be placed on a plain piece of heated glaſs or metal, ſo that each ſide of it, by being perpendicular to the ſurface of the heated body, may be equally heated; it will, while heating, have the electricity of one of its ſides poſitive, and that of the other negative. This will, likewiſe, be the caſe when it is taken out of boiling water and ſuffered to cool; but the ſide which was poſitive while it was heating will be negative while it is cooling, and the ſide which was negative will be poſitive.

IN this paper Mr. Canton refers to the Gentleman's Magazine for the month of September before, in which he had publiſhed the reſult of ſome experiments he had made on a tourmalin which he had procured from Holland. The propoſitions he there lays down are ſo few, and compriſe the principal part of what is known upon this ſubject in ſo conciſe and elegant a manner, that I ſhall recite them all in this place.

1. WHEN the tourmalin is not electrical or attractive, heating it, without friction, will make

make it ſo; and the electricity of one ſide of it (diſtinguiſhed by A) will be poſitive, and that of the other ſide (B) will be negative.

2. THE tourmalin not being electrical will become ſo by cooling; but with this difference, that the ſide A will be negative, and the ſide B poſitive.

3. IF the tourmalin, in a non-electrical ſtate, be heated, and ſuffered to cool again, without either of its ſides being touched; A will be poſitive, and B negative, the whole time of the increaſe and decreaſe of its heat.

4. EITHER ſide of the tourmalin will be poſitive by friction, and both may be made ſo at the ſame time.

THESE, ſays he, are the principal laws of the electricity of this wonderful ſtone; and he adds, if air be ſuppoſed to be endued with ſimilar properties, i. e. of becoming electrical by the increaſe or diminution of its heat (as is probable, if its ſtate before and after a thunder ſtorm be attended to) thunder clouds both poſitive and negative, as well as thunder guſts, may eaſily be account for.

THESE capital diſcoveries were made before Mr. Canton had received of Dr. Heberden the tourmalins above mentioned. When thoſe came to his hands he was enabled to make ſeveral new and curious experiments, which I have leave to publiſh.

HE put one of the tourmalins, which was of the common colour into the flame from a blow-pipe and burnt it white; when he found

that

that its electrical property was intirely deſtroyed. The electricity of another was only in part deſtroyed by the fire. Two other tourmalins he joined together, when they were made ſoft by fire, without deſtroying their electrical property. The virtue of another was improved by its being melted at one end; and he found (contrary to what Mr. Wilſon had obſerved of another tourmalin, which he treated in the ſame manner) that one tourmalin retained its electrical property after it had been frequently made red-hot, and, in that ſtate, put into cold water.

But the moſt curious of his experiments were made upon a large irregular tourmalin, about half an inch in length, which he cut into three pieces; taking one part from the poſitive, and another from the negative end. Trying theſe pieces ſeparately, he found the outer ſide of the piece which he cut from the end that was negative when cooling was likewiſe negative when cooling, and that the outer ſide of that piece which was cut from the end that was poſitive when cooling was likewiſe poſitive when cooling; the oppoſite ſides of both pieces being, agreeable to the general law of the electricity of the tourmalin, in a contrary ſtate.

The middle part of the ſame tourmalin was affected juſt as it had been when it was intire; the poſitive end remained poſitive, and the negative end continued negative. The ſame he had alſo obſerved of two other tourmalins,

malins, each about the ſize of this, which were alſo cut out of a large one.

ON January the 8th, 1762, Mr. Canton took the Doctor's large tourmalin (which Mr. Wilſon has given a deſcription of in the fifty-firſt volume of the Philoſophical Tranſactions, p. 316.) and having placed a ſmall tin cup of boiling-water on one end of his electrometer, which was ſupported by warm glaſs, while the pith balls were ſuſpended at the other end; he dropped it into the water, and obſerved, that during the whole time of its being heated, and alſo while it was cooling in the water, the balls were not at all electrified.

TILL the year 1760 it had been ſuppoſed, that, of all electric ſubſtances, the tourmalin alone poſſeſſed the property of being excited by heating and cooling; but in the beginning of that year, Mr. Canton having had an opportunity of examining a variety of gems, by the favour of Mr. Nicolas Criſp a jeweller in Bow Church-yard, firſt found the *Brazil topaz* to have the electrical properties of the tourmalin. The largeſt he met with he put into the hands of Dr. Heberden, who returned it November the 27th, 1760, and ſent with it the tourmalins above mentioned.

IN September 1761, Mr. Wilſon (who had been informed of Mr. Canton's diſcovery) met with ſeveral other gems, of different ſizes and colours, that reſembled the tourmalin with reſpect to electrical experiments. The moſt beautiful of them were ſomething like the ruby,

ruby, others were more pale, and one inclining to an orange colour. In point of hardneſs and luſtre, they were nearly the ſame with the topaz.

From all his experiments upon theſe gems he thought it was abundantly evident, that the direction of the fluid did not depend upon the external figure of the gem, but upon ſome particular internal make and conſtitution of it. And that there is ſome ſuch natural diſpoſition in all gems affording theſe appearances may be collected, he ſays, from another curious ſpecimen of the tourmalin kind, which is green, and formed of long ſlender cryſtals with ſeverals ſides; many of which are found ſticking together, and are brought from South America.

These gems, numbers of which were furniſhed him by Mr. Emanuel Mendes Da Coſta, he not only found to be like the tourmalin with reſpect to electric appearances; but that the direction of the electric fluid moving therein was always along the grain or ſhootings of the cryſtals, one end of it being electrified *plus*, and the other end *minus*. And that the fluid is more diſpoſed to paſs in that direction than in another, he thought, might be farther collected from what has been obſerved on the grain of the loadſtone by Dr. Knight; who found that though the magnetic poles of the natural loadſtone might be varied in any direction, yet that the ſame loadſtone admitted of being made much more magnetical along the grain than acroſs it.

From these experiments and observations Mr. Wilson inferred by analogy, that the electric fluid, flowing through all these stones and gems, moves in that direction in which the grain happens to lie; and that the reason of this is, that the resistance which the fluid meets with in passing through the gem is less in that direction than in any other *.

In a subsequent paper of Mr. Wilson's, read at the Royal Society December the 23d, 1763, and March 1764, he recites several curious experiments on the effects of removing the tourmalin from one room to another, in which there was some difference of heat; the result of which exactly confirms Mr. Canton's discovery, that the side which is positive when heating is negative when cooling, and *vice versa*. Upon a very nice examination, and during some favourable circumstances, Mr. Wilson says he has observed the tourmalin to be feebly electrified, when the thermometer varied up and down only one degree †.

* Phil. Transf. Vol. lii. pt. ii. p. 443.
† Ibid. p. 457.

SECTION

SECTION X.

DISCOVERIES THAT HAVE BEEN MADE SINCE THOSE OF DR. FRANKLIN, WITH RESPECT TO THE SAMENESS OF LIGHTNING AND ELECTRICITY.

THE year 1752 makes an æra in electricity no leſs famous than the year 1746, in which the Leyden phial was diſcovered. In the year 1752, was verified the hypotheſis of Dr. Franklin, of the identity of the matter of lightning and of the electric fluid; and his great project of trying the experiment by real lightning actually brought down from the clouds, was carried into execution.

THE French philoſophers were the firſt to diſtinguiſh themſelves upon this memorable occaſion, and the moſt active perſons in the ſcene were Mr. Dalibard and Delor, both zealous partiſans (as Mr. Nollet calls them) of Dr. Franklin. The former prepared his apparatus at Marly La Ville, ſituated five or ſix leagues from Paris, the other at his own houſe, on ſome of the higheſt ground in that capital. Mr. Dalibard's machine conſiſted of an iron rod forty feet long, the lower extremity of which was brought into a centry box, where the rain could not come; while, on the outſide, it was faſtened to three wooden poſts by long ſilken ſtrings defended from the rain.

rian. This machine happened to be the firſt that was favoured with a viſit from this ethereal fire. The philoſopher himſelf happened not to be at home at that time; but, in his abſence, he entruſted the care of his apparatus to one Coiffier a joiner, a man who had ſerved fourteen years among the dragoons, and on whoſe underſtanding and courage he could depend. This artiſan had all proper inſtructions given him, both how to make obſervations, and alſo to guard himſelf from any harm there might be from them; beſides being expreſsly ordered to get ſome of his neighbours to be preſent, and particularly to ſend for the curate of Marly, whenever there ſhould be any appearance of the approach of a thunder ſtorm. At length the long expected event arrived.

On Wedneſday the 10th of May 1752, between two and three o'clock in the afternoon, Coiffier heard a pretty loud clap of thunder. Immediately he flies to the machine, takes a phial furniſhed with a braſs wire, and preſenting one end of the wire to the rod, he ſees a ſmall bright ſpark iſſue from it, and hears the ſnapping that it made. Taking a ſecond ſpark ſtronger than the former, and attended with a louder report, he calls his neighbours, and ſends for the curate. The curate runs with all his might, and the pariſhioners, ſeeing the precipitation of their ſpiritual guide, imagine that poor Coiffier had been killed with lightning. The alarm ſpreads through the village, and the hail which came on did not prevent

vent the flock from following their ſhepherd. The honeſt eccleſiaſtic arriving at the machine, and ſeeing there was no danger, took the wire into his own hand, and immediately drew ſeveral ſtrong ſparks, which were moſt evidently of an electrical nature, and completed the diſcovery for which the machine was erected.

THE thunder cloud was not more than a quarter of an hour in paſſing over the zenith of the machine, and there was no thunder heard beſides that ſingle clap. As ſoon as the ſtorm was over, and no more ſparks could be drawn from the bar, the curate wrote a letter to Mr. Dalibard, containing an account of this remarkable experiment, and ſent it immediately by the hands of Coiffier himſelf.

HE ſays, that he drew ſparks from the bar of a blue colour, an inch and a half in length, and which ſmelled ſtrong of ſulphur. He repeated the experiment at leaſt ſix times in the ſpace of about four minutes, in the preſence of many perſons, each experiment taking up the time, as he, in the ſtile of a prieſt expreſſes himſelf, of a *pater* and an *ave*. In the courſe of theſe experiments he received a ſtroke on his arm, a little above the elbow, but he could not tell whether it came from the braſs wire inſerted into the phial, or from the iron bar. He did not attend to the ſtroke at the time he received it, but, the pain continuing, he uncovered his arm when he went home, in the preſence of Coiffier; and a mark was perceived round his arm, ſuch as might have

have been made by a blow with the wire on his naked ſkin; and afterwards ſeveral perſons, who knew nothing of what had happened, ſaid that they perceived a ſmell of ſulphur when he came near them.

COIFFIER told Mr. Dalibard, that for about a quarter of an hour before the curate arrived, he had, in the preſence of five or ſix perſons, taken much ſtronger ſparks than thoſe which the curate mentioned *.

EIGHT days after, Mr. Delor ſaw the ſame thing at his own houſe, although only a cloud paſſed over, without either thunder or lightning †.

THE ſame experiments were afterwards repeated by Mr. Delor, at the requeſt of the king of France, who, it is ſaid, ſaw them with the greateſt ſatisfaction, and expreſſed a juſt ſenſe of the merit of Dr. Franklin. Theſe applauſes of the king excited in Mr. De Buffon, Dalibard, and Delor, a deſire of verifying Dr. Franklin's hypotheſis more completely, and of purſuing his ſpeculations upon the ſubject.

MR. DELOR's apparatus in Paris conſiſted of a bar of iron ninety-nine feet high, and anſwered rather better than that of Mr. Dalibard, which, as was obſerved before, was only forty feet high. But as the quantity of electricity which they could procure from the clouds, in theſe firſt experiments, was but ſmall, they added to this apparatus what they

* Dalibard's Franklin, Vol. ii. p. 109, &c.
† Nollet's Letters, Vol. i. p. 9.

called

called a *magazine* of electricity, consisting of many bars of iron insulated, and communicating with the pointed iron rod. This magazine contained more of the electric matter, and gave a more sensible spark, upon the approach of the finger than the pointed bar.

A MAGAZINE of this kind Mr. Mazeas had in an upper room of his house, into which he brought the lightning, by means of a wooden pole projecting out of his window, at the extremity of which a glass tube, filled with rosin, received a pointed iron rod, twelve feet long. But all this while the electrics, which they made use of to support these iron rods, were too much exposed to the open air, and consequently were liable to be wet, which would infallibly defeat their experiments.

THE most accurate experiments, made with these imperfect instruments, where those of Mr. Monnier. He was convinced that the high situation in which the bar of iron had commonly been placed was not absolutely necessary for this purpose: for he observed a common speaking-trumpet, suspended upon silk five or six feet from the ground, to exhibit very evident signs of electricity. He also found that a man placed upon cakes of rosin, and holding in his hand a wooden pole, about eighteen feet long, about which an iron wire was twisted, was so well electrified when it thundered, that very lively sparks were drawn from him; and that another man, standing upon non-electrics, in the middle of

 a garden,

a garden, and only holding up one of his hands in the air, attracted, with the other hand, ſhavings of wood which were held to him.

He ſays, that he obſerved a continual diminution of the electricity when the rain came on, though the thunder was ſtill very loud, and though the cake of roſin which ſupported his conductor was not wet. But he afterwards found, that this was not univerſally true.

He once obſerved, that when the conducting wire was ſurrounded with drops of rain, only ſome of them were electrified, as was evident from the conical figure they had, while the reſt remained round as before. It was alſo perceived, that the electrified and non-electrified drops generally ſucceeded each other alternately; which made Mr. Monnier call to mind a ſingular phenomenon, which happened ſome years before to five peaſants who were paſſing through a corn field, near Frankfort upon the Oder, during a thunder ſtorm; when the lightning killed the firſt, the third, and the fifth of them, without injuring the ſecond or the fourth *.

It was not owing to any want of attention to this ſubject that the Engliſh philoſophers were not the firſt to verify the theory of Dr. Franklin. They happened to have few opportunities of trying experiments. In the few they had, they were diſappointed by

* Phil. Tranſ. Vol. xlvii. p. 551.

the

the rain wetting their apparatus, which was not better conſtructed than that of the French.

At length ſucceſs crowned the aſſiduity and happier contrivance of Mr. Canton, who, to the lower end of his conducting wire, had had the precaution to faſten a tin cover, to keep the rain from the glaſs tube which ſupported it. By this means, on the 20th of July 1752, he got ſparks at the diſtance of half an inch, but the whole appearance ceaſed in the ſpace of two minutes *.

Mr. Wilson, who took great pains in theſe purſuits, as he did in every thing elſe relating to electricity, perceiving ſeveral electrical ſnaps, on the 12th of Auguſt following, from no other apparatus than an iron curtain rod; one end of which he put into the neck of a glaſs phial, which he held in his hand, while the other was made to point into the air.

Dr. Bevis alſo, at this time, viz. on the 12th of Auguſt, obſerved nearly the ſame appearances that Mr. Canton had done before †.

Mr. Canton afterwards, reſuming his obſervations on lightning, with the aſſiduity and accuracy with which he obſerves every thing, found, by a great number of experiments, that ſome clouds were in a poſitive, and ſome in a negative ſtate of electricity. And that, by this means, the electricity of

* Phil. Tranſ. Vol. xlvii. p. 568.
† Ibid. p 569.

his conductor would ſometimes change from one ſtate to the other five or ſix times in leſs than half an hour *.

THIS obſervation of Mr. Canton, on the different electricity of the clouds was made, and the account of it publiſhed in England, before it was known that Dr. Franklin had made the ſame diſcovery in America.

WHEN the air was dry, he obſerved, that the apparatus would continue electrified for ten minutes, or a quarter of an hour after the clouds had paſſed the zenith, and ſometimes till they were more than half way towards the horizon; that rain, eſpecially when the drops were large, generally brought down the electric fire; and hail in ſummer, he believed, never failed. The laſt obſervation he had made before the time of his writing this paper, when his apparatus had been electrified by a fall of thawing ſnow. This was on the 12th of November 1753, which, he ſays, was the 26th day, and the ſixty-firſt time, it had been electrified ſince it was firſt ſet up, viz. about the middle of the preceding May.

ONLY two thunder ſtorms had happened at London during that whole ſummer, and Mr. Canton's apparatus was ſo ſtrongly electrified by one of them, that the ringing of the bells (which he ſuſpended to his apparatus, to ſignify when the electrification was begun, and which were frequently rung ſo loud as to be heard in every room in the

* Phil. Tranſ. Vol. xlviii. pt. i. p. 356.

houſe)

house) was stifled by the almost constant stream of dense electric fire between each bell and the brass ball, which would not suffer it to strike.

UPON a farther occasion, he observes, that in the succeeding months of January, February, and March, his apparatus was electrified no less than twenty-five times, both positively and negatively, by snow as well as by hail and rain; and almost to as great a degree when Fahrenheit's thermometer was between twenty-eight and thirty-four, as he had ever known it in summer, except in a thunder-storm *.

MR. CANTON concludes his paper with proposing the two following queries. 1. May not air suddenly rarefied give electric fire to, and air suddenly condensed receive electric fire from clouds and vapours passing through it? 2. Is not the aurora borealis the flashing of electric fire from positive towards negative clouds at a great distance, through the upper part of the atmosphere, where the resistance is least †?

MR. CANTON not only observed the different states of positive and negative electricity in the clouds, but also noted the proportion that the one bore to the other for a considerable time. In the first period he had observed the clouds had been positively electrical 83 times, and negative 101. In this period he

* Phil. Transf. Vol. xlviii. pt. ii. p. 785.
† Ibid. pt. i. p. 358.

had punctually ſet down how often the powers had ſhifted, and the whole time that the apparatus continued to be electrified, but he had intirely neglected to note the time that each power laſted. But this laſt circumſtance he afterwards carefully attended to for about two months, viz. from the 28th of June to the 23d of Auguſt 1754; and found the apparatus to be electrified poſitively thirty-one times, which taken together laſted three hours thirty-five minutes; and negatively forty-five times, the whole duration of which was ten hours thirty-nine minutes. He alſo obſerved that the poſitive power was generally the ſtronger. This account he wrote the 31ſt of Auguſt 1754.

These obſervations, which Mr. Canton gives me leave to make public, are extremely curious, and muſt have required great attention; but they are hardly ſufficient to authorize any general concluſion.

One of the effects of lightning and electricity is the melting of metals. This was firſt thought to be a cold fuſion; but that opinion is refuted, in a very ſenſible manner, by Dr. Knight, in a paper read at the Royal Society, November 22d, 1759. He obſerves, that the inſtances moſt generally given of cold fuſion are two, viz. that of a ſword being melted in its ſcabbard, and that of money being melted in a bag, both the ſcabbard and the bag remaining unhurt.

A great number of authors, he ſays, have mentioned both the facts, but without giving

giving either their own teſtimony, or that of any one elſe for the truth of them, or deſcribing any of the other concomitant circumſtances. And it ſeemed to him very poſſible, that lightning might produce effects ſimilar to thoſe above mentioned, without our being obliged to have recourſe to a cold fuſion to account for them.

If, ſays he, the edge or external ſurface of a ſword had been melted, whilſt the main part of the blade remained entire, it would have afforded ſufficient ground to aſſert, in general terms, that the ſword was melted, and yet the ſcabbard might have remained unhurt; becauſe either the edge or ſurface of a ſword might be inſtantly melted by lightning and cooled ſo ſuddenly, as to make no impreſſion of burning upon the ſcabbard. Metals, as well as other bodies, he obſerves, will both heat and cool ſooner in proportion as they are thin and ſlender; that very ſmall wire will inſtantly become red hot, and even melt, and run into a round globule in the flame of a common candle; though it is no ſooner removed out of the flame, but it is inſtantly cold He therefore concludes, that the edge of a ſword, or even its ſurface, might be inſtantly melted by lightning; and being in contact with, or rather ſtill united to the reſt of the blade, which might be cold, it would part with its heat too ſuddenly to produce any appearance of burning.

He was confirmed in this reaſoning, by examining ſome fragments and particles of

wire melted by lightning, which were sent him by Mr. Mountaine. Amongst them appeared globules of various sizes, which had undergone very different degrees of fusion. The largest of them had not been fluid enough to put on a sperical figure, but they approached nearer to it, in proportion as they were smaller; so that, in the smallest granulæ, the fusion was most perfect, the globules being very round and smooth. Their sizes continued diminishing till they became invisible to the naked eye, and some of them, when viewed with a microscope, required a third or fourth magnifier to see them distinctly.

Some of the bits of wire were rough and scaly, like burnt iron, and were swelled in those places where they were beginning to melt. Others continued straight, and of an equable thickness; but their outward surface seemed to have undergone a perfect fusion, so that there were two or more pieces adhering together, as if joined by a thin solder.

In the Philosophical Transactions, Dr. Knight says, there are two or three relations which seemed at first to favour a cold fusion, but when duly considered prove nothing conclusive *.

But that there is really no such thing as cold fusion, either by electricity or lightning, was most clearly demonstrated by Mr. Kinnersley, in a letter to Dr. Franklin, dated Philadelphia, March 12th, 1761.

* Phil. Transf. Vol. li. pt. i. p. 294, &c.

He ſuſpended a piece of ſmall braſs wire, about twenty-four inches long, with a pound weight at the lower end; and, by ſending through it the charge of a caſe of bottles, containing above thirty feet of coated glaſs, he diſcovered what he calls a new method of wire-drawing. The wire was red-hot, the whole length well annealed, and above an inch longer than before. A ſecond charge melted it ſo that it parted near the middle, and meaſured, when the ends were put together, four inches longer than at firſt.

This experiment, he ſays, was propoſed to him by Dr. Franklin, in order to find whether the electricity, in paſſing through the wire, would ſo relax the coheſion of its conſtituent particles, as that the weight might produce a ſeparation; but neither of them had the leaſt ſuſpicion that any heat would be produced.

That he might have no doubt of the wire being *hot*, as well as *red*, he repeated the experiment on another piece of the ſame wire, encompaſſed with a gooſe quill, filled with looſe grains of gun-powder; which took fire, as readily as if it had been touched with a red-hot poker. Alſo tinder, tied to another piece of the wire, kindled by it; but when he tried a wire about twice as big, he could produce no ſuch effects.

Hence, ſays he, it appears, that the electric fire, though it has no ſenſible heat, when in a ſtate of reſt, will, by its violent motion, and the reſiſtance it meets with, produce heat in

in other bodies, when paſſing through them, provided they be ſmall enough. A great quantity will paſs through a large wire, without producing any ſenſible heat; when the ſame quantity, paſſing through a very ſmall one, being there confined to a narrower paſſage, the particles crowding cloſer together, and meeting with a greater reſiſtance, will make it red-hot, and even melt it.

Hence, he concludes, that lightning does not melt metal by a cold fuſion, as Dr. Franklin and himſelf had formerly ſuppoſed; but that, when it paſſed through the blade of a ſword, if the quantity was not very great, it might heat the point ſo as to melt it, while the broadeſt and the thickeſt part might not be ſenſibly warmer than before.

When trees and houſes are ſet on fire by the dreadful quantity, which a cloud, or ſometimes the earth diſcharges, muſt not the heat, ſays he, by which the wood is firſt kindled, be generated by the lightning's violent motion through the reſiſting combuſtible matter?

If lightning, by its rapid motion, produced heat in itſelf as well as in other bodies (which Mr. Kinnerſley imagined was evident from ſome experiments made with electrical thermometer, mentioned before) he thought that its ſometimes ſingeing the hair of animals killed by it might eaſily be account for; and that the reaſon of its not always doing ſo might be, that the quantity, though ſufficient to kill a large animal, might not be great enough

enough, or not have met with refiftance enough, to become by its motion burning-hot.

We find, fays he, that dwelling-houfes ftruck with lightning, are feldom fet on fire by it; but that when it paffes through barns, with hay or ftraw in them, or ftore-houfes containing large quantities of hemp, or fuch like matter, they feldom, if ever, efcape a conflagration. This, he thought, might be owing to fuch combuftibles being apt to kindle with a lefs degree of heat than was neceffary to kindle wood *.

All that was done by the French and Englifh electricians, with refpect to lightning and electricity, fell far fhort of what was done by Signior Beccaria at Turin. His attention to the various ftates of the atmofphere, his affiduity in making experiments, his apparatus for making them, the extent of his views in making them, the minute exactnefs with which he has recorded them, and his judgment in applying them to a general theory, far exceeded every thing that had been done by philofophers before him, or that has been done by any perfon fince. And though I fhall give confiderable fcope to my account of his experiments and obfervations, I fhall be able to give my reader but a faint idea of the extent, variety, and value of his labours in this great field.

* Phil. Tranf. Vol. liii. p. 92, &c.

He made uſe both of kites and pointed rods, and of a great variety of both at the ſame time, and in different places. Some of the ſtrings of his kites had wires in them, and others had none. Some of them flew to a prodigious height, and others but low; and he had a great number of aſſiſtants, to note the nature, time, and degree of appearances, according as his views required.

To keep his kites conſtantly inſulated, and at the ſame time to give them more or leſs ſtring, and for many other purpoſes, he had the ſtring rolled upon a reel, which was ſupported by pillars of glaſs; and his conductor had a communication with the axis of the reel *.

To diſtinguiſh the poſitive and negative ſtate of the clouds, when the electricity was vigorous, with more certainty, and with more ſafety than it could be done by preſenting an excited ſtick of glaſs, or ſealing-wax to threads diverging from his conductor; he incloſed a pointed wire and a flat piece of lead oppoſite to it within a cylindrical glaſs veſſel, wrapped in paſteboard, ſo that the inſide could have no communication with the external light. Into this cover, and oppoſite to the point of the wire, he inſerted a very long tube of paſteboard; through which he could look from a conſiderable diſtance, and ſee the form of the electric light at the end of the

* Lettere dell' elettriciſmo, p. 112.

wire;

wire; which is the fureſt indication of its quality *.

From Signior Beccaria's extremely exact and circumſtantial account of the external appearances of thunder clouds, which he prefixes to his obſervations on their probable cauſes, I ſhall draw a general outline of the moſt remarkable particulars, in the uſual progreſs of a thunder ſtorm.

The firſt appearance of a thunder ſtorm (which generally happens when there is little or no wind) is one denſe cloud, or more, increaſing very faſt in ſize, and riſing into the higher regions of the air. The lower ſurface is black, and nearly level; but the upper finely arched, and well defined. Many of theſe clouds often ſeem piled one upon another, all arched in the ſame manner; but they keep continually uniting, ſwelling, and extending their arches.

At the time of the riſing of this cloud, the atmoſphere is generally full of a great number of ſeparate clouds, motionleſs, and of odd and whimſical ſhapes. All theſe, upon the appearance of the thunder cloud, draw towards it, and become more uniform in their ſhapes as they approach; till, coming very near the thunder cloud, their limbs mutually ſtretch towards one another; they immediately coaleſce, and together make one uniform maſs. Theſe he calls *adſcititious* clouds, from their coming in, to enlarge the ſize of the

* Lettere dell' elettriciſmo, p. 107.

thunder cloud. But, ſometimes the thunder cloud will ſwell, and increaſe very faſt without the conjunction of any adſcititious clouds, the vapours in the atmoſphere forming themſelves into clouds wherever it paſſes. Some of the adſcititious clouds appear like white fringes, at the ſkirts of the thunder cloud, or under the body of it, but they keep continually growing darker and darker, as they approach to unite with it.

When the thunder cloud is grown to a great ſize, its lower ſurface is often ragged, particular parts being detached towards the earth, but ſtill connected with the reſt. Sometimes the lower ſurface ſwells into various large protuberances bending uniformly towards the earth. And ſometimes one whole ſide of the cloud will have an inclination to the earth, and the extremity of it will nearly touch the earth *. When the eye is under the thunder cloud, after it is grown larger, and well formed, it is ſeen to ſink lower, and to darken prodigiouſly; at the ſame time that a number of ſmall adſcititious clouds (the origin of which can never be perceived) are ſeen in a rapid motion, driving about in very uncertain directions under it. While theſe clouds are agitated with the moſt rapid motions, the rain generally falls in the greateſt plenty, and if the agitation be exceedingly great, it commonly hails †.

* Lettere dell' elettriciſmo, p. 151.
† Ibid. p. 155.

While

WHILE the thunder cloud is ſwelling, and extending its branches over a large tract of country, the lightning is ſeen to dart from one part of it to another, and often to illuminate its whole maſs. When the cloud has acquired a ſufficient extent, the lightning ſtrikes between the cloud and the earth, in two oppoſite places, the path of the lightning lying through the whole body of the cloud and its branches. The longer this lightning continues, the rarer does the cloud grow, and the leſs dark is its appearance; till, at length, it breaks in different places, and ſhows a clear ſky. When the thunder cloud is thus diſperſed, thoſe parts which occupy the upper regions of the atmoſphere are equally ſpread, and very thin; and thoſe that are underneath are black, but thin too: and they vaniſh gradually, without being driven away by any wind *.

HAVING ſeen what this philoſopher obſerved abroad, and in the air, let us ſee what he took notice of at his apparatus within doors. This never failed to be electrified upon every approach of a thunder cloud, or any of its branches; and the ſtream of fire from it was generally perpetual, while it was directly over the apparatus †.

THAT thunder clouds were ſometimes in a poſitive as well as negative ſtate of electricity, Signior Beccaria had diſcovered, before he heard of its having been obſerved by Dr. Franklin,

* Lettere dell' elettriciſmo, p 146. 176.
† Ibid. p 167.

Franklin, or any other person *. The same cloud, in passing over his observatory, electrified his apparatus, sometimes positively, and sometimes negatively †. The electricity continued longer of the same kind, in proportion as the thunder cloud was simple, and uniform in its direction; but when the lightning changed its place, there commonly happened a change in the electricity of his apparatus. It would change suddenly after a very violent flash of lightning, but the change would be gradual when the lightning was moderate, and the progress of the thunder cloud slow.

It was an immediate inference from his observations of the lightning abroad, and his apparatus within, that the quantity of electric matter, in an usual storm of thunder, is almost inconceivably great, considering how many pointed bodies, as trees, spires, &c. are perpetually drawing it off, and what a prodigious quantity is repeatedly discharged to, or from the earth ‡.

After this summary view of appearances, I shall, in the same succinct manner explain the hypothesis by which this excellent philosopher accounts for them, and some other principal and well known phenomena of thunder storms.

Considering the vast quantity of electric fire that appears in the most simple thunder storms, he thinks it impossible that any cloud, or number of clouds should ever contain it all,

* Lettere dell' elletricismo, p. 138. † Ibid. p. 172.
‡ Ibid. p. 180.

all, ſo as either to diſcharge or receive it. Beſides, during the progreſs and increaſe of the ſtorm, though the lightning frequently ſtruck to the earth, the ſame clouds were the next moment ready tó make a ſtill greater diſcharge, and his apparatus continued to be as much affected as ever. The clouds muſt, conſequently, have received at one place, the moment that a diſcharge was made from them in another *. In many caſes, the electricity of his apparatus, and conſequently of the clouds, would inſtantly change from one kind to another ſeveral times; an effect which cannot be accounted for by any ſimple diſcharge, or recruit. Both muſt have taken place in a very quick ſucceſſion †.

The extent of the clouds doth not leſſen this difficulty: for, be it ever ſo great, ſtill the quantity ought to be leſſened by every diſcharge: and, beſides, the points, by which the ſilent diſcharges are made, are in proportion to the extent of the clouds ‡. Nor is the difficulty leſſened by ſuppoſing that freſh clouds bring recruits; for beſides that the clouds are not ripe for the principal ſtorm, till all the clouds, to a great diſtance, have actually coaleſced, and formed one uniform maſs, thoſe recruits bear no ſort of proportion to the diſcharge, and whatever it was, it would ſoon be exhauſted.

The fact, therefore, muſt be, that the electric matter is continually darting from the

* Lettere dell' elettriciſmo, p. 183. 188.
† Ibid. p. 220. ‡ Ibid. p. 185.

clouds in one place, at the ſame time that it is diſcharged from the earth in another. And it is a neceſſary conſequence from the whole, that the clouds ſerve as conductors to convey the electric fluid from thoſe places of the earth which are overloaded with it, to thoſe which are exhauſted of it *.

To aſcertain this fact in the moſt complete manner, he propoſes that two obſervatories be fixed, about two leagues aſunder, in the uſual path of the thunder clouds; and that obſervations be made, whether the apparatus be not often poſitive at one place, when it is negative at the other †.

THAT great quantities of electric matter do ſometimes ruſh out of particular parts of the earth, and riſe through the air, into the higher regions of the atmoſphere, he thinks is evident from the great quantities of ſand, aſhes, and other light ſubſtances, which have often been carried up into the air, and ſcattered uniformly over a large tract of country ‡. No other known efficient cauſe of this phenomenon can be aſſigned, except the wind; and it has been obſerved when there was no wind ſtirring; and the light bodies have even been carried againſt the wind §. He ſuppoſes, therefore, that theſe light bodies are raiſed by a large quantity of electric matter iſſuing out of the earth, where it was overcharged with it, and (by that property of it which he had demonſtrated) attracting, and

* Lettere dell' elettriciſmo, p. 193. † Ibid. p. 194. ‡ Ibid. p. 199. § Ibid. p. 225.

carry-

carrying with it every ſubſtance that could ſerve as a conductor in its paſſage. All theſe bodies, being poſſeſſed of an equal quantity of the electric fluid, will be diſperſed equally in the air, and conſequently over that part of the earth where the fluid was wanting, and whither they ſerve to convey it *. Had theſe bodies been raiſed by the wind, they would have been diſperſed at random, and in heaps.

THIS comparatively rare phenomenon (but of which he had been more than once a ſpectator) he thinks exhibits both a perfect image, and a demonſtration, of the manner in which the vapours of the atmoſphere are raiſed to form thunder clouds. The ſame electric matter, wherever it iſſues, attracts to it, and carries up into the higher regions of the air, the watery particles that are diſperſed in the atmoſphere. The electric matter aſcends to the higher regions of the atmoſphere, being ſolicited by the leſs reſiſtance it finds there than in the common maſs of the earth; which, at thoſe times, is generally very dry, and conſequently highly electric. The uniformity with which thunder clouds ſpreads themſelves, and ſwell into arches, muſt be owing to their being affected by ſome cauſe which, like the electric matter, diffuſes itſelf uniformly whereever it acts, and to the reſiſtance they meet with in aſcending through the air †. As a proof of this, ſteam, riſing from an electrified eolipile, diffuſes itſelf with the ſame uni-

* Lettere dell' elettriciſmo, p. 202. † Ibid. p. 205.

formity, and in similar arches, extending itself towards any conducting substance *.

The same cause which first raised a cloud, from vapours dispersed in the atmosphere, draws to it those that are already formed, and continues to form new ones, till the whole collected mass extends so far as to reach a part of the earth where there is a deficiency of the electric fluid †. Thither too, will those clouds, replete with electricity, be strongly attracted, and there will the electric matter discharge itself upon the earth. A channel of communication being, in this manner, found, a fresh supply of electric matter will be raised from the overloaded part, and will continue to be conveyed by the medium of the clouds, till the equilibrium of the fluid between the two places of the earth be restored. When the clouds are attracted in their passage by those parts of the earth where there is a deficiency of the fluid, those detached fragments are formed, and also those uniform depending protuberances, which will be shown to be, in some cases, the cause of water-spouts and hurricanes ‡.

That the electric matter, which forms and animates the thunder clouds, issues from places far below the surface of the earth, and that it buries itself there, is probable from the deep holes that have, in many places, been made by lightning §. Flashes of lightning have, also, been seen to arise from subterrane-

* Lettere dell' elettricismo, p. 206. † Ibid. p. 212.
‡ Ibid. p. 214. § Ibid. p. 227.

ous

ous cavities, and from wells *. Violent inundations have accompanied thunder ſtorms, not occaſioned by rain, but by water burſting from the bowels of the earth, from which it muſt have been diſlodged by ſome internal concuſſion. Deep wells have been known to fill faſter in thunder ſtorms †, and others have conſtantly grown turbid at the approach of thunder ‡.

This very riſe, as well as the whole progreſs of thunder clouds, has ſometimes been, in a manner, viſible. Exhalations have been frequently ſeen to riſe from particular caverns, attended with a rumbling noiſe, and to aſcend into the higher regions of the air, with all the phenomena of thunder ſtorms deſcribed above, according to the deſcription of perſons who lived long before the connection between electricity and lightning was ſuſpected §.

The greateſt difficulty attending this theory of the origin of thunder ſtorms relates to the collection, and inſulation of electric matter within the body of the earth. With reſpect to the former, he has nothing particular to ſay. Some operations in nature are certainly attended with a loſs of the equilibrium in the electric fluid, but no perſon has yet aſſigned a more probable cauſe of the redundancy of the electric matter which, in fact, often abounds in the clouds, than what we may ſuppoſe

* Lettere dell' elettriciſmo, p. 228.
† Ibid. p. 233.
‡ Ibid. p. 360.
§ Ibid. p. 231.

possible to take place in the bowels of the earth. And supposing the loss of the equilibrium possible, the same cause that produced the effect would prevent the restoring of it; so that not being able to force a way, at least one sufficiently ready, through the body of the earth, it would issue at the most convenient vent into the higher regions of the air, as the better passage. His electrical apparatus, though communicating with the earth, has frequently, in violent thunder storms, given evident sparks to his finger*.

In the enumeration of the effects of thunder storms, he observes that a wind always blows from the place from which the thunder cloud proceeds; that this is agreeable to the observations of all mariners, and that the wind is more or less violent in proportion to the suddeness of the appearance of the thunder cloud, the rapidity of its expansion, and the velocity with which the adscititious clouds join it. The sudden condensation of such a prodigious quantity of vapours must displace the air, and repel it on all sides †.

He, in some measure, imitated even this effect of thunder, at least produced a circulation of all the air in his room, by the continued electrification of his chain ‡.

Among other effects of lightning, he mentions the case of a man rendered exceedingly stiff, presently after he was struck dead in a storm of thunder. But the most remarkable

* Lettere dell' elettricismo, p. 236. † Ibid. p. 339, 340.
‡ Ibid. p. 343.

circum-

circumſtance, in this caſe, was the lightning (chuſing the beſt conductor) having ſtruck one particular vein, near his neck, and followed it through its minuteſt ramifications; ſo that the figure of it appeared through the ſkin, finer than any pencil could have drawn it *.

He cautions perſons not to depend upon the neighbourhood of a higher, or, in all caſes, a better conductor than their own body; ſince, according to his repeated obſervations, the lightning by no means deſcends in one undivided track; but bodies of various kinds conduct their ſhare of it, at the ſame time, in proportion to their quantity and conducting power †.

A great number of obſervations, relating to the deſcent of lightning, confirm his theory of the manner of its aſcent: for, in many caſes, it throws before it the parts of conducting bodies, and diſtributes them along the reſiſting medium through which it muſt force its paſſage ‡.

Upon this principle it is, that the longeſt flaſhes of lightning ſeem to be made, by its forcing into its way part of the vapours in the air §. One of the principal reaſons why thoſe flaſhes make ſo long a rumbling, is their being occaſioned by the vaſt length of a vacuum, made by the paſſage of the electric matter. For though the air collapſes the mo-

* Lettere dell' elettriciſmo, p. 242. † Ibid. p. 246.
‡ Ibid. p. 247. § Ibid. p. 851.

ment after it has paſſed, and the vibration (on which the ſound depends) commences at the ſame moment, through the whole length of the track; yet, if the flaſh was directed towards the perſon who hears the report, the vibrations excited at the nearer end of the track will reach his ear much ſooner than thoſe excited at the more remote end; and the ſound will, without any repercuſſion or echo, continue till all the vibrations have ſucceſſively reached him *.

I MUST introduce in this place a very curious experiment and obſervation of Mr. Lullin, concerning the production of electricity in the clouds. He made a long inſulated pole project from the ſide of one of the Alps; and, on the 29th of June 1766, obſerved, that when ſmall clouds of vapour, raiſed by the heat of the ſun, roſe near the foot of the mountain, and aſcended along the ſide of it; if they touched the extremity of the pole only, it was electrified; but if the whole pole, and conſequently part of the hill on which it ſtood, was likewiſe involved, it was not electrified. From this he concludes, that the electricity of the clouds is produced by their paſſing through the air while the ſun ſhines upon them. But to which of theſe two circumſtances, namely the motion through the air, or the action of the ſun's rays, this was owing, he could not determine, though he made ſeveral experiments for that purpoſe †.

* Lettre dell' elettriciſmo, p. 252.

† Diſſertatio phyſica, p. 42.

ONE

One of the moſt remarkable effects of lightning is that it gives polarity to the magnetic needle, and to all bodies that have any thing of iron in them, as bricks, &c. and by obſerving which way the poles of theſe bodies lye, it may be known, with the utmoſt certainty, in what direction the ſtroke paſſed *. In one caſe S. Beccaria actually aſcertained the direction of the lightning in this manner †.

Since a ſudden ſtroke of lightning gives polarity to magnets, he conjectures that a regular and conſtant circulation of the whole maſs of the fluid, from North to South, may be the original cauſe of magnetiſm in general ‡. This is a truly great thought; and, if juſt, will introduce greater ſimplicity into our conceptions of the laws of nature.

That this etherial current is inſenſible to us, is no proof of its non-exiſtence, ſince we ourſelves are involved in it. He had ſeen birds fly ſo near a thunder cloud, as he was ſure they would not have done, if they had been affected by its atmoſphere §.

This current he would not ſuppoſe to ariſe from one ſource, but from ſeveral, in the northern hemiſphere of the earth. The aberration of the common center of all theſe currents from the North point may be the cauſe of the variation of the needle, the period of this declination of the center of the currents may be the period of the variation, and the obliquity with which the currents ſtrike into the

* Lettere dell' elettriciſmo, p. 262. † Ibid. p. 263.
‡ Ibid. p. 268. § Ibid.

earth

earth may be the cause of the dipping of the needle, and also why bars of iron more easily receive the magnetic virtue in one particular direction *.

He thinks that the *Aurora Borealis* may be this electric matter performing its circulation, in such a state of the atmosphere as renders it visible, or approaching nearer to the earth than usual. Accordingly very vivid appearances of this kind have been observed to occasion a fluctuation in the magnetic needle †.

Stones and bricks struck by lighning are often vitrified. He supposes that some stones in the earth, having been struck in this manner, first gave occasion to the vulgar opinion of the thunder bolt ‡.

Signior Beccaria was very sensible that heat contributes much to the phenomena of thunder, lightning, and rain; but he could not find, by any experiment, that it tended to promote electricity. He, therefore, rather thought that heat operated, in this case, by exhaling the moisture of the air, and thereby cutting off the communication of the electric fluid between one place and another, particularly between the earth and the higher regions of the air, whereby its effects were more visible §.

Having entertained my reader with the observations of this great Italian genius, I must once more conduct him to France, where he will see several experiments well worth his notice.

* Lettere dell' elettricismo, p. 269. † Ibid. p. 272.
‡ Ibid. p. 263. § Ibid. p. 359.

notice. In this country we have ſeen that Dr. Franklin's theory of the identity of electricity and the matter of lightning was firſt verified, and we ſhall now ſee it verified in the grandeſt and moſt conſpicuous manner.

THE greateſt quantity of electricity that was ever brought from the clouds, by any apparatus prepared for that purpoſe, was by Mr. De Romas, aſſeſſor to the preſideal of Nerac. This gentleman was the firſt who made uſe of a wire interwoven in the hempen cord of an electrical kite, which he made ſeven feet and a half high, and three feet wide, ſo as to have eighteen ſquare feet of ſurface. This cord was found to conduct the electricity of the clouds more powerfully than a hempen cord would do, even though it was wetted; and, being terminated by a cord of dry ſilk it enabled the obſerver (by a proper management of his apparatus) to make whatever experiments he thought proper, without danger to himſelf.

BY the help of this kite, on the 7th of June 1753, about one in the afternoon, when it was raiſed 550 feet from the ground, and had taken 780 feet of ſtring, making an angle of near forty-five degrees with the horizon; he drew ſparks from his conductor three inches long and a quarter of an inch thick, the ſnapping of which was heard about 200 paces. Whilſt he was taking theſe ſparks, he felt, as it were, a cobweb on his face, though he was above three feet from the ſtring of the kite; after which he did not think it ſafe to ſtand

ſo

ſo near, and called aloud to all the company to retire, as he did himſelf about two feet.

THINKING himſelf now ſecure enough, and not being incommoded by any body very near him, he took notice of what paſſed among the clouds which were immediately over the kite; but could perceive no lightning either there or any where elſe, nor ſcarce the leaſt noiſe of thunder, and there was no rain at all. The wind was Weſt, and pretty ſtrong, which raiſed the kite 100 feet higher, at leaſt, than in the other experiments.

AFTERWARDS, caſting his eyes on the tin tube, which was faſtened to the ſtring of the kite, and about three feet from the ground, he ſaw three ſtraws, one of which was about one foot long, a ſecond four or five inches, and the third three or four inches, all ſtanding erect, and performing a circular dance, like puppets, under the tin tube, without touching one another.

THIS little ſpectacle, which much delighted ſeveral of the company, laſted about a quarter of an hour; after which, ſome drops of rain falling, he again perceived the ſenſation of the cobweb on his face, and at the ſame time heard a continual ruſtling noiſe, like that of a ſmall forge bellows. This was a farther warning of the increaſe of electricity; and from the firſt inſtant that Mr. De Romas perceived the dancing ſtraws, he thought it not adviſeable to take any more ſparks even with all his precautions; and he again

again intreated the company to ſpread themſelves to a ſtill greater diſtance.

IMMEDIATELY after this came on the laſt act of the entertainment, which Mr. De Romas acknowledged made him tremble. The longeſt ſtraw was attracted by the tin tube, upon which followed three exploſions, the noiſe of which greatly reſembled that of thunder. Some of the company compared it to the exploſion of rockets, and others to the violent craſhing of large earthen jars againſt a pavement. It is certain that it was heard into the heart of the city, notwithſtanding the various noiſes there.

THE fire that was ſeen at the inſtant of the exploſion had the ſhape of a ſpindle eight inches long and five lines in diameter. But the moſt aſtoniſhing and diverting circumſtance was produced by the ſtraw, which had occaſioned the exploſion, following the ſtring of the kite. Some of the company ſaw it at forty-five or fifty fathoms diſtance, attracted and repelled alternately, with this remarkable circumſtance, that every time it was attracted by the ſtring, flaſhes of fire were ſeen, and cracks were heard, though not ſo loud as at the time of the former exploſion.

IT is remarkable, that, from the time of the exploſion to the end of the experiments, no lightning at all was ſeen, nor ſcarce any thunder heard. A ſmell of ſulphur was perceived, much like that of the luminous electric effluvia iſſuing out of the end of an electrified bar of metal. Round the ſtring appeared

peared a luminous cylinder of light, three or four inches in diameter; and this being in the day-time Mr. De Romas did not queſtion but that, if it had been in the night, that electric atmoſphere would have appeared to be four or five feet in diameter. Laſtly, after the experiments were over, a hole was diſcovered in the ground, perpendicularly under the tin tube, an inch deep, and half an inch wide, which was probably made by the large flaſhes that accompanied the exploſions.

An end was put to theſe remarkable experiments by the falling of the kite, the wind being ſhifted into the Eaſt, and rain mixed with hail coming on in great plenty. Whilſt the kite was falling, the ſtring came foul of a penthouſe; and it was no ſooner diſengaged, than the perſon who held it felt ſuch a ſtroke in his hands, and ſuch a commotion through his whole body, as obliged him inſtantly to let it go; and the ſtring, falling on the feet of ſome other perſons, gave them a ſhock alſo, though much more tolerable *.

The quantity of electric matter brought by this kite from the clouds at another time is really aſtoniſhing. On the 26th of Auguſt 1756, the ſtreams of fire iſſuing from it were obſerved to be an inch thick, and ten feet long. This amazing flaſh of lightning, the effect of which on buildings or animal bodies, would perhaps have been equally deſtructive with any that are mentioned in hiſtory, was

* Gent. Magaz. for Auguſt 1756, p. 378.

ſafely

ſafely conducted by the cord of the kite to a non-electric body placed near it, and the report was equal to that of a piſtol.

Mr. Romas had the curioſity to place a pigeon in a cage of glaſs, in a little edifice, which he had purpoſely placed, ſo as that it ſhould be demoliſhed by the lightning brought down by his kite. The edifice was, accordingly, ſhattered to pieces, but the cage and the pigeon were not ſtruck *.

The Abbé Nollet, who gives this account, adds, that if a ſtroke of this kind had gone through the body of Mr. De Romas, the unfortunate profeſſor Richman had not probably been the only martyr to electricity, and adviſes, that great caution be uſed in conducting ſuch dangerous experiments †.

When we conſider how many ſevere ſhocks the moſt cautious and judicious electricians often receive through inadvertence, we ſhall not be ſurpriſed, that when philoſophers firſt began to collect and make experiments upon real lightning, it ſhould ſometimes have proved a little untractable in their hands, and that they were obliged to give one another frequent cautions how to proceed with it.

The Abbé Nollet, as early as the year 1752, adviſes that theſe experiments be made with circumſpection; as he had been informed, by letters from Florence and Bologna, that thoſe who had made them there had had

* Nollet's Letters, Vol. ii. p. 239.
† Phil. Tranſ. Vol. lii. pt. i. p. 342.

their

their curiofity more than fatisfied by the violent fhocks they had fuftained in drawing fparks from an iron bar electrified by thunder. One of his correfpondents informed him, that once, as he was endeavouring to faften a fmall chain, with a copper ball at one of its extremities, to a great chain, which communicated with the bar at the top of the building (in order to draw off the electric fparks by means of the ofcillations of this ball) there came a flafh of lightning, which he did not fee, but which affected the chain with a noife like that of wild fire. At that inftant, the electricity communicated itfelf to the chain of the copper ball, and gave the obferver fo violent a commotion, that the ball fell out of his hands, and he was ftruck backwards four or five paces. He had never been fo much fhocked by the experiment of Leyden *.

Mr. Romas received a fevere ftroke when he firft raifed his kite: and Mr. Dalibard fays, that Mr. Monnier, a phyfician of St. Germain en Laye, member of the Academy of Sciences at Paris, and Mr. Bertier of the Oratory at Montmorency, a correfpondent of the Academy, were both ftruck down by ftrokes of lightning, as they were taking fparks from their apparatus †.

But the greateft fufferer by experiments with lightning, fince mankind have introduced fo dangerous a fubject of their inquiries, was profeffor Richman of Peterfburgh

* Phil. Tranf. Vol. xlviii. pt. i. p. 205.
† Dalibard's Franklin, Vol. ii. p. 129.

before

before mentioned. He was ſtruck dead, on the 6th of Auguſt 1753, by a flaſh of lightning drawn by his apparatus into his own room, as he was attending to an experiment he was making with it. There were two accounts of this fatal accident communicated to the Royal Society, one by Dr. Watſon who had it from the beſt authority*; and the other tranſlated from the High Dutch †. From both theſe the following is extracted.

The profeſſor had provided himſelf with an inſtrument which he called an *electrical gnomon*, the uſe of which was to meaſure the ſtrength of electricity. It conſiſted of a rod of metal terminating in a ſmall glaſs veſſel, into which (for what reaſon I do not know) he put ſome braſs filings. At the top of this rod, a thread was faſtened, which hung down by the ſide of the rod when it was not electrified; but when it was, it avoided the rod, and ſtood at a diſtance from it, making an angle at the place where it was faſtened. To meaſure this angle, he had the arch of a quadrant faſtened to the bottom of the iron rod.

He was obſerving the effect of the electricity of the clouds, at the approach of a thunder ſtorm, upon this gnomon; and, of courſe, ſtanding with his head inclined towards it, accompanied by Mr. Solokow (an engraver, whom he frequently took with him, to be a

* Phil. Tranſ. Vol. xlviii. pt. ii. p. 765.
† Ibid. Vol. xlix. pt. i. p. 61.

joint obſerver of his electrical experiments, in order to repreſent them the better in cuts) when this gentleman, who was ſtanding cloſe to his elbow, obſerved a globe of blue fire, as he called it, as big as his fiſt, jump from the rod of the gnomon towards the head of the profeſſor, which was, at that inſtant, at about a foot diſtance from the rod. This flaſh killed Mr. Richman, but Mr. Solokow could give no account of the particular manner in which he was immediately affected by it: for, at the ſame time that the profeſſor was ſtruck, there aroſe a ſort of ſteam, or vapour, which intirely benumbed him, and made him ſink down upon the ground; ſo that he could not remember even to have heard the clap of thunder, which was very loud.

THE globe of fire was attended with a report as loud as that of a piſtol: a wire, which brought the electricity to his metal rod, was broken to pieces, and its fragments thrown upon Mr. Solokow's cloaths. Half of the glaſs veſſel in which the rod of the gnomon ſtood was broken off, and the filings of metal that were in it were thrown about the room.

UPON examining the effects of the lightning in the profeſſor's chamber, they found the door-caſe half ſplit through, and the door torn off, and thrown into the room *. They opened a vein of the breathleſs body twice, but no blood followed, and endeavoured to re-

* Phil. Tranſ. Vol. xlviii. pt. ii. p. 763.

cover

cover ſenſation by violent chafing, but in vain. Upon turning the corpſe with the face downwards, during the rubbing, an inconſiderable quantity of blood ran out of the mouth. There appeared a red ſpot on the forehead, from which ſpirted ſome drops of blood through the pores, without wounding the ſkin. The ſhoe belonging to the left foot was burſt open, and, uncovering the foot at that place, they found a blue mark; from which it was concluded, that the electrical force of the thunder, having entered the head, made its way out again at that foot.

Upon the body, particularly on the left ſide, were ſeveral red and blue ſpots, reſembling leather ſhrunk by being burnt. Many more blue ſpots were afterwards viſible over the whole body, and in particular over the back. That upon the forehead changed to a browniſh red, but the hair of the head was not ſinged, notwithſtanding the ſpot touched ſome of it. In the place where the ſhoe was unripped, the ſtocking was intire; as was the coat every where, the waiſtcoat only being ſinged on the foreflap, where it joined the hinder; but there appeared on the back of Mr. Solokow's coat long narrow ſtreaks, as if red hot wires had burned off the nap, and which could not be well accounted for.

When the body was opened the next day, twenty-four hours after he was ſtruck, the cranium was very intire, having no fiſſure,

nor crofs opening; the brain as found as it poffibly could be, but the tranfparent pellicles of the windpipe were exceffively tender, gave way, and eafily rent. There was fome extravafated blood in it, as likewife in the cavities below the lungs; thofe of the breaft being quite found, but thofe towards the back of a brownifh black colour, and filled with more of the above mentioned blood: otherwife, none of the entrails were touched; but the throat, the glands, and the thin inteftines were all inflamed. The finged leather-coloured fpots penetrated the fkin only. Twice twenty-four hours being elapfed, the body was fo far corrupted that it was with difficulty they got it into a coffin*.

* Phil. Tranf. Vol. xlix. pt. i. p. 67.

SECTION

SECTION XI.

OBSERVATIONS ON THE GENERAL STATE OF ELECTRICITY IN THE ATMOSPHERE, AND ITS MORE USUAL EFFECTS.

ELECTRICIANS, after observing the great quantity of electric matter with which the clouds are charged during a thunder storm, began to attend to the lesser quantities of it which might be contained in the common state of the atmosphere, and the more usual effects of this great and general agent in nature. Mr. Monnier, whose observations of the electricity of the air during a thunder storm have been already mentioned, was the first who found that there was very often, and perhaps always, a quantity of electric matter in the atmosphere, when there was no appearance of thunder. This he confirmed by decisive experiments, made at St. Germain en Laye, and published in a memoir read at the Royal Academy of Sciences at Paris November the 15th, 1752 *.

BUT more accurate experiments upon the electricity of the air were made by the Abbé Mazeas, at Chateau de Maintenon, during the months of June, July, and October 1753, and communicated to the Royal Society, in a letter to Dr. Stephen Hales.

* Phil. Transf. Vol. xlviii. pt. i. p. 203.

The Abbé's apparatus confifted of an iron rod 370 feet long, raifed ninety feet above the horizon. It came down from a very high room in the caftle, where it was faftened to a filken cord fix feet long; and it was carried from thence to the fteeple of the town, where it was likewife faftened to another filken cord of eight feet long, and fheltered from rain. And a large key was fufpended, by the end of this wire, in order to receive the electric fluid.

On the 17th of June, when he began his experiments, the electricity of the air was fenfibly felt every day, from fun rife till feven or eight in the evening, except in moift weather, when he could perceive no figns of electricity. In dry weather, the wire attracted minute bodies at no greater diftance than three or four lines. He repeated the experiment carefully every day, and conftantly obferved, that, in weather void of ftorms, the electricity of a piece of fealing-wax of two inches long was above twice as ftrong as that of the air. This obfervation inclined him to conclude, that in weather of equal drinefs the electricity of the air was always equal.

It did not appear to him that hurricanes and tempefts increafed the electricity of the air, when they were not accompanied with thunder; for that, during three days of a very violent continual wind, in the month of July, he was obliged to put fome duft within four or five lines of the conductor, before any fenfible attraction could be perceived.

The

THE direction of the winds, whether East, West, North, or South, made no sensible alteration in the electricity of the air, except when they were moist.

IN the driest nights of that summer, he could discover no signs of electricity in the air; but it returned in the morning when the sun began to appear above the horizon, and vanished again in the evening, about half an hour after sun-set.

THE strongest common electricity of the atmosphere, during that summer, was perceived in the month of July, on a very dry day, the heavens being very clear, and the sun extremely hot. The distance of ten or twelve lines was then sufficient for the approach of the dust to the conductor, in order to see the particles rise in a vertical direction, like the filings of iron on the approach of a magnet.

ON the 27th of June, at two in the afternoon, he perceived some stormy clouds rising above the horizon, and immediately went up to his apparatus; and, having applied the dust to the key, it was attracted with a force which increased in proportion as the clouds reached the zenith. When they had come nearly over the wire, the dust was so impetuously repelled, as to be entirely scattered from the paper. He drew considerable sparks from it, though there was neither thunder nor lightning. When the stormy clouds were in the zenith of his wire, he observed that the electricity was increased to such a degree, that

even the silken thread attracted light bodies at the distance of seven or eight inches.

THESE stormy clouds remained about two hours above the horizon, without either thunder or lightning; nor did a very heavy rain diminish the electricity, except about the end, when the clouds began to be dissipated *.

MR. KINNERSLEY observed, that when the air was in its driest state, there was always a considerable quantity of electricity in it, and which might be easily drawn from it. Let a person, he says, in a negative state, standing out of doors, in the dark, when the air is dry, hold, with his arm extended, a long sharp needle, pointing upwards, and he will soon be convinced that electricity may be drawn out of the air; not indeed very plentifully, for, being a bad conductor, it seems loth to part with it, yet some will evidently be collected. The air near the person's body, having less than the natural quantity, will have none to spare; but his arm being extended, as above, some will be collected from the remoter air, and will appear luminous as it converges to the point of the needle.

LET a person electrified negatively, he says, present the point of a needle horizontally, to a cork ball suspended by silk, and the ball will be attracted towards the point, till it has parted with so much of its natural quantity of electricity, as to be in a negative state, in the

* Phil. Trans. Vol. xlviii. pt. i. p. 377, &c.

same

ſame degree with the perſon who holds the needle; then it will recede from the point, being, as he ſuppoſes, attracted the contrary way by the electricity of greater denſity in the air behind it. But as this opinion, he pleaſantly ſays, ſeems to deviate from *electrical orthodoxy*, he would be glad to ſee theſe phenomena better accounted for by the ſuperior and more penetrating genius of his friend Dr. Franklin, to whom he is writing.

WHETHER the electricity in the air, in clear dry weather, be of the ſame denſity at the height of 200 or 300 yards, as near the ſurface of the earth, he thought might be ſatisfactorily determined by Dr. Franklin's old experiment of the kite.

THE twine, he ſays, ſhould have throughout a very ſmall wire in it, and the ends of the wire, where the ſeveral lengths are united, ought to be tied down with a waxed thread, to prevent their acting in the manner of points.

WHEN he wrote this letter, he had tried the experiment twice, when the air was as dry as it ever is in that country, and ſo clear, that not a cloud had been ſeen, and found the twine each time in a ſmall degree electrified poſitively *.

THE preceding obſervations of Mr. Monnier, Mr. Mazeas, and Mr. Kinnerſley, fall far ſhort of the extent and accuracy of thoſe of Signior Beccaria; whoſe obſervations on

* Phil. Tranſ. Vol. liii. pt. i. p. 87.

the general ſtate of electricity in the atmoſphere I have reſerved for the laſt place of the ſection, becauſe they are the moſt conſiderable though they were all made independent of, and, many of them, prior to thoſe mentioned before.

He obſerved that, during very high winds, his apparatus gave no ſigns of being electrified *. Indeed he found that in three different ſtates of the atmoſphere, he could find no electricity in the air. 1. In windy and clear weather. 2. When the ſky was covered with diſtinct and black clouds, that had a ſlow motion. 3. In moiſt weather, not actually raining †. In a clear ſky, when the weather was calm, he always perceived ſigns of a moderate electricity, but interrupted. In rainy weather, without lightning, his apparatus was always electrified a little time before the rain fell, and during the time of the rain, but it ceaſed to be affected a little before the rain was over.

The higher his rods reached, or his kites flew, the ſtronger ſigns they gave of their being electrified ‡. Alſo longer ſtrings or cords, extended and inſulated in the open air, acquired electricity ſooner than thoſe which were ſhorter. A cord 1500 Paris feet long, ſtretched over the river Po, was as ſtrongly electrified during a ſhower, without thunder, as a metallic rod, to bring lightning

* Lettere dell' elettriciſmo, p. 106.
† Ibid. p. 166. ‡ Ibid. p. 114.

into

into his houſe, had been in any thunder ſtorm *.

HAVING two rods for bringing the lightning into his houſe, 140 feet aſunder, he obſerved, that if he took a ſpark from the higher of them, the ſpark from the other, which was thirty feet lower, was at that inſtant leſſened; but, what is remarkable, is that its power revived again, though he kept his hand upon the former †.

HE imagined that the electricity communicated to the air might ſometimes furniſh ſmall ſparks to his apparatus; ſince the air parts with the electricity it has received very ſlowly, and therefore the equilibrium of the electric matter in the air will not be reſtored ſo ſoon as in the earth and clouds ‡.

AMONG the effects of a moderate electricity in the atmoſphere, Signior Beccaria reckons *rain*, *hail*, and *ſnow*.

CLOUDS that bring rain, he thought, were produced in the ſame manner as thunder clouds, only by a more moderate electricity. He deſcribes them at large, and the reſemblance which all their phenomena bear to thoſe of thunder clouds is indeed very ſtriking §.

HE notes ſeveral circumſtances attending rain without lightning, which make it very probable, that it is produced by the ſame cauſe as when it is accompanied with lightning. Light has been ſeen among the clouds by

* Lettere dell' elettriciſmo, p. 165. † Ibid. p. 175.
‡ Ibid. p. 347. § Ibid. p. 284.

night in rainy weather; and even by day rainy clouds are sometimes seen to have a brightness evidently independent of the sun *. The uniformity with which the clouds are spread, and with which the rain falls, he thought were evidences of an uniform cause like that of electricity †. The intensity of electricity in his apparatus generally corresponded very nearly, to the quantity of rain that fell in the same time ‡. Nor is any thing to be inferred to the contrary of this supposition from the apparatus not being always electrified during rain. It has sometimes failed during thunder. Indeed it follows from his general theory, that the electricity of his apparatus could not always correspond to the electricity of the clouds; since it must in some measure depend upon the situation of the observatory, with respect to those parts of the earth or clouds which are giving or taking electric fire. This was confirmed by an observation which he made upon one thunder cloud, which passed over his observatory. At its approach his apparatus was electrified positively, when it was directly over him all signs of electricity ceased, and when it was passed, his apparatus was electrified negatively §. This observation very much favours his general theory of thunder clouds.

SOMETIMES all the phenomena of thunder, lightning, hail, rain, snow, and wind, have

* Lettere dell' elettricismo, p. 288. † Ibid, p. 299.
‡ Ibid. p. 307. § Ibid. p. 310.

been obſerved at one time; which ſhows the connection they all have with ſome common cauſe *.

Signior Beccaria, therefore, ſuppoſes that, previous to rain, a quantity of electric matter eſcapes out of the earth, in ſome place where there was a redundancy of it; and, in its aſcent to the higher regions of the air, collects and conducts into its path a great quantity of vapours. The ſame cauſe that collects, will condenſe them more and more: till, in the places of the neareſt intervals, they come almoſt into contact, ſo as to form ſmall drops; which uniting with others as they fall, come down, in rain. The rain will be heavier in proportion as the electricity is more vigorous, and the cloud approaches more nearly to a thunder cloud †.

He imitated the appearance of clouds that bring rain by inſulating himſelf between the rubber and conductor of his electrical machine, and with one hand dropping *colophonia* into a ſpoon faſtened to the conductor, and holding a burning coal, while his other hand communicated with the rubber. In theſe circumſtances the ſmoke ſpread along his arm, and, by degrees, all over his body, till it came to the other hand that communicated with the rubber. The lower ſurface of this ſmoke was every where parallel to his cloaths, and the upper ſurface was ſwelled and arched like clouds replete with thunder and rain ‡. In

* Lettere dell' elettriciſmo, p. 290. 345. † Ibid. p. 305.
‡ Ibid. p. 294.

this

this manner, he ſuppoſes, the clouds that bring rain diffuſe themſelves from over thoſe parts of the earth which abound with electric fire, to thoſe parts that are exhauſted of it; and, by letting fall their rain, reſtore the equilibrium between them.

SIGNIOR BECCARIA thought that the electricity communicated to the air, which both receives and parts with it ſlowly, would account for the retention of vapours in a clear ſky; for ſmall disjoined clouds, not diſperſed into rain; for the ſmaller and lighter clouds in the higher regions of the air, which are but little affected by electricity; and alſo for the darker, heavy, and ſluggiſh clouds in the lower regions, which retain more of it *. The degree of electricity which he could communicate to the air of his room, notwithſtanding its being in contact with the floor, the walls, &c. made this appear to him both poſſible and probable †.

HE even imagined, that ſome alteration in the weight of the air might be made by this electricity of it ‡. He obſerved his barometer to fall a little immediately upon a flaſh of lightning; but he acknowledges that this circumſtance is no ſufficient foundation to ſuppoſe that electricity will account for *much* variation of the height of the barometer §. But he thought that the phenomena of rain favoured the ſuppoſition, that the electric matter in the air did, in ſome meaſure, leſſen its preſ-

* Lettere dell' elettricifmo, p. 348, 349.
† Ibid. p. 350. ‡ Ibid. § Ibid. p. 353.

ſure.

ſure. For when the electric matter is actually in the air, collecting and condenſing the vapours, the barometer is loweſt. When the communication is made between the earth and the clouds by the rain, the quickſilver begins to riſe; the electric matter, which ſupported part of the preſſure, being diſcharged. And this, he ſhows, will be the caſe whether the electricity in the air be poſitive or negative *.

HAIL, this ingenious philoſopher ſuppoſes to be formed in the higher regions of the air, where the cold is intenſe, and where the electric matter is very copious. In theſe circumſtances, a great number of particles of water are brought near together, where they are frozen, and in their deſcent collect other particles: ſo that the denſity of the ſubſtance of the hail-ſtone grows leſs and leſs from the center; this being formed firſt, in the higher regions, and the ſurface being collected in the lower. Agreeable to this, it is obſerved, that, in mountains, hail-ſtones, as well as drops of rain, are very ſmall; there being but ſmall ſpace through which they can fall, and thereby increaſe their bulk. Drops of rain and hail agree alſo in this circumſtance, that the more intenſe is the electricity that forms them, the larger they are †. Motion is known to promote freezing, and ſo the rapid motion of the electrified clouds may promote that effect in the air ‡.

* Lettere dell' ellettricifmo, p. 354. † Ibid. p. 314.
‡ Ibid. p. 318,

CLOUDS

Clouds of ſnow differ in nothing from clouds of rain, but in the circumſtance of cold, which freezes them. Both the regular diffuſion of ſnow, and the regularity in the ſtructure of the parts of which it conſiſts (particularly ſome figures of ſnow or hail, which he calls *roſette*, and which fall about Turin) ſhow the clouds of ſnow to be actuated by ſome uniform cauſe, like electricity *. He even endeavours, very particularly, to ſhow in what manner certain configurations of ſnow are made, by the uniform action of electricity †. All theſe conjectures about the cauſe of hail and ſnow were confirmed by obſerving, that his apparatus never failed to be electrified by ſnow, as well as by rain.

A more intenſe electricity unites the particles of hail more cloſely than the more moderate electricity does thoſe of ſnow. In like manner, we ſee thunder clouds more denſe than thoſe which merely bring rain, and the drops of rain are larger in proportion, though they often fall not from ſo great a height ‡.

I shall conclude this ſection with obſerving, that profeſſor Winthrop found his apparatus to be ſtrongly electrified for ſeveral hours, while the ſnow, which fell the day before (and which had not electrified his apparatus while it was falling) was driven about by a high wind the ſame he had obſerved twice before. Franklin's Letters, new edition, p. 494.

* Lettere dell' ellettriciſmo, p. 320. 322. 325.
† Ibid. p. 325. 331. 333. ‡ Ibid. p. 328.

SECTION XII.

THE ATTEMPTS THAT HAVE BEEN MADE TO EXPLAIN SOME OF THE MORE UNUSUAL APPEARANCES IN THE EARTH AND HEAVENS BY ELECTRICITY.

IN the two preceding ſections of this period, relating to the electricity of the atmoſphere, the experiments and obſervations of Signior Beccaria have made a principal figure; and the materials I have collected from him make a no leſs conſiderable part of this. They who may have thought he indulged too much to imagination before, will think him abſolutely extravagant here; but his extravagancies, if they be ſuch, are thoſe of a great genius; and had he a thouſand more ſuch extravagancies, I ſhould, with pleaſure, have followed him through them all.

THE meteor, uſually called a *falling ſtar*, has hitherto puzzled all philoſophers. Signior Beccaria makes it pretty evident, that it is an electrical appearance; and the fact which he relates as a proof of it, is exceedingly curious and remarkable.

As he was one time ſitting with a friend in the open air, an hour after ſun-ſet, they ſaw what is called a falling ſtar directing its courſe towards them, and apparently growing larger and larger, till it diſappeared not far

 from

from them; when it left their faces, hands, and cloaths, with the earth, and all the neighbouring objects, suddenly illuminated, with a diffused and lambent light, attended with no noise at all. While they were starting up, standing, and looking at one another, surprised at the appearance, a servant came running to them out of a neighbouring garden, and asked them if they had seen nothing; for that he had seen a light shine suddenly in the garden, and especially upon the streams which he was throwing to water it *.

ALL these appearances were evidently electrical; and Signior Beccaria was confirmed in his conjecture, that electricity was the cause of them, by the quantity of electric matter which, as was mentioned before, he had seen gradually advancing towards his kite; for that, he says, had very much the appearance of a falling star. Sometimes also he saw a kind of *glory* round the kite, which followed it when it changed its place, but left some light, for a small space of time, in the place which it had quitted †.

THAT appearances, which bear evident marks of electricity, have a very sensible progressive motion, is demonstrated from a variety of meteorological observations. I shall relate one made by Mr. Chalmers, when he was on board the Montague under the command of Admiral Chambers. The account of it

* Lettere dell' elettricismo, p. 111.
† Ibid. p. 130.

was read at the Royal Society, March the 22d, 1749.

On the 4th of November 1749, in lat. 42° 48′ long. 9° 3′ he was taking an observation on the quarter-deck, about ten minutes before twelve, when one of the quarter-masters desired he would look to the windward; upon which he observed a large ball of blue fire rolling on the surface of the water, at about three miles distance from them. They immediately lowered their top-sails, &c. but it came down upon them so fast, that before they could raise the main-tack, they observed the ball to raise almost perpendicular, and not above forty or fifty yards from the main-chains; when it went off with an explosion as if hundreds of cannon had been fired at one time, and left so great a smell of brimstone, that the ship seemed to be nothing but sulphur. After the noise was over, which, he believed, did not last longer than half a second, they found their main top-mast shattered into above a hundred pieces, and the main mast rent quite down to the heel. There were some of the spikes which nail the fish of the main-mast drawn with such force out of the mast, and they stuck so fast in the main-deck, that the carpenter was obliged to take an iron crow to get them out. There were five men knocked down, and one of them greatly burnt by the explosion. They believed, that when the ball, which appeared to them to be of the bigness of a large mill-stone, rose, it took the middle of the main top-mast, as the

 head

head of the maſt above the hounds was not ſplintered. They had a hard gale of wind from the N. by W. to the N. N. E. for two days before the accident, with a great deal of rain and hail, and a large ſea. From the northward they had no thunder or lightning, neither before nor after the exploſion. The ball came down from the North-Eaſt, and went to the South-Weſt.

THAT the *Aurora Borealis* is an electrical phenomenon was, I believe never diſputed, from the time that lightning was proved to be one. To the circumſtances of reſemblance which had before been taken notice of between this phenomenon and electricity; Signior Beccaria adds, that when the *Aurora Borealis* has extended lower than uſual into the atmoſphere, various ſounds, as of rumbling, and hiſſing, have been heard *.

MR. BERGMAN ſays, he has often obſerved the magnetic needle to be diſturbed by a high aurora borealis, but that he could never procure any electricity from them, either with pointed metallic rods, or by means of a kite †.

MR. CANTON (beſides his conjecture, mentioned before, p. 389, that the aurora borealis may be the flaſhing of electric fire from poſitive towards negative clouds at a great diſtance, through the upper part of the atmoſphere, where the reſiſtance is leaſt) ſuppoſes that the aurora borealis, which happens

* Elettriciſmo artificiale e naturale, p. 221.
† Phil. Tranſ. Vol. lii. pt. ii. p. 485.

at

at the time that the needle is disturbed by the heat of the earth, is the electricity of the heated air above it; and this, he says, will appear chiefly in the northern regions, as the alteration in the heat of the air in those parts will be the greatest. This hypothesis, he adds, will not seem improbable, if it be considered, that electricity is now known to be the cause of thunder and lightning, that it has been extracted from the air at the time of an aurora borealis; that the inhabitants of the northern countries observe the aurora to be remarkably strong, when a sudden thaw happens after severe cold weather; and that the curious in these matters are now acquainted with a substance that will, without friction, both emit and absorb the electric fluid, only by the increase or diminution of its heat; meaning the tourmalin, in which he had discovered that property *.

In a paper, dated November the 11th, 1754, he says he has sometimes known the air to be electrical in clear weather, but never at night, except when there has appeared an aurora borealis, and then but to a small degree, which he had several opportunities of observing that year. How far positive and negative electricity in the air, with a proper quantity of moisture between, to serve as a conductor, will account for this, and other meteors, sometimes seen in a serene sky, he leaves to be inquired into †.

* Phil. Transf. Vol. li. pt. i. p. 403.
† Ibid. Vol. xlviii. pt. ii. p. 784.

SIGNIOR BECCARIA takes some pains to show that *water spouts* have an electrical origin. To make this more evident, he first describes the circumstances attending their appearance, which are the following.

THEY generally appear in calm weather. The sea seems to boil, and send up a smoke under them, rising in a hill towards the spout. At the same time, persons who have been near them have heard a rumbling noise. The form of a water spout is that of a speaking-trumpet, the wider end being in the clouds, and the narrower end towards the sea. The size is various, even in the same spout. The colour is sometimes inclining to white, and sometimes to black. Their position is sometimes perpendicular to the sea, sometimes oblique; and sometimes the spout itself is in the form of a curve. Their continuance is very various, some disappearing as soon as formed, and some continuing a considerable time. One that he had heard of continued a whole hour. But they often vanish, and presently appear again in the same place *.

THE very same things that water spouts are at sea are some kinds of *whirlwinds* and *hurricanes* by land. They have been known to tear up trees, to throw down buildings, make caverns in the earth; and, in all these cases, to scatter earth, bricks, stones, timber, &c. to a great distance in every direction †. Great

* Elettricismo artificiale e naturale, p. 206, &c.
† Ibid. p. 210.

quantities

quantities of water have been left, or raiſed by them, ſo as to make a kind of deluge; and they have always been attended with a prodigious rumbling noiſe.

THAT theſe phenomena depend upon electricity cannot but appear very probable from the nature of ſeveral of them; but the conjecture is made more probable from the following additional circumſtances. They generally appear in months peculiarly ſubject to thunder ſtorms, and are commonly preceded, accompanied, or followed by lightning, rain, or hail; the previous ſtate of the air being ſimilar. Whitiſh or yellowiſh flaſhes of light have ſometimes been ſeen moving with prodigious ſwiftneſs about them. And, laſtly, the manner in which they terminate exactly reſembles what might be expected from the prolongation of one of the uniform protuberances of electrified clouds, mentioned before, towards the ſea; the water and the cloud mutually attracting one another: for they ſuddenly contract themſelves, and diſperſe almoſt at once; the cloud riſing, and the water of the ſea under it falling to its level. But the moſt remarkable circumſtance, and the moſt favourable to the ſuppoſition of their depending upon electricity is, that they have been diſperſed by preſenting to them ſharp pointed knives or ſwords. This, at leaſt, is the conſtant practice of mariners, in many parts of the world where theſe water ſpouts abound; and he was aſſured by ſeveral of them, that

the method has often been undoubtedly effectual *.

The analogy between the phenomena of water spouts and electricity, he says, may be made visible, by hanging a drop of water to a wire communicating with the prime conductor, and placing a vessel of water under it. In these circumstances, the drop assumes all the various appearances of a water spout, both in its rise, form, and manner of disappearing. Nothing is wanting but the smoke, which may require a great force of electricity to become visible.

Mr. Wilcke also considers the water spout as a kind of great electrical cone, raised between the cloud strongly electrified, and the sea or the earth †, and he relates a very remarkable appearance which occurred to himself, and which strongly confirms his supposition. On the 20th of July 1758, at three o'clock in the afternoon, he observed a great quantity of dust rising from the ground, and covering a field, and part of the town in which he then was. There was no wind, and the dust moved gently towards the East, where there appeared a great black cloud, which, when it was near his zenith, electrified his apparatus positively, and to as great a degree as ever he had observed it to be done by natural electricity. This cloud passed his zenith, and went gradually towards the West, the dust then following it, and continuing to

* Elettricismo artificiale e naturale, p. 213.
† Wilcke, p. 142.

rise

riſe higher and higher till it compoſed a thick pillar, in the form of a ſugar-loaf, and at length ſeemed to be in contact with the cloud. At ſome diſtance from this, there came, in the ſame path, another great cloud, together with a long ſtream of ſmaller clouds, moving faſter than the preceding. Theſe clouds electrified his apparatus negatively, and when they came near the poſitive cloud, a flaſh of lightning was ſeen to dart through the cloud of duſt, the poſitive cloud, the large negative cloud, and as far as the eye could diſtinguiſh, the whole train of ſmaller negative clouds which followed it. Upon this, the negative clouds ſpread very much, and diſſolved in rain, and the air was preſently clear of all the duſt. The whole appearance laſted not above half an hour *.

To Signior Beccaria's theory of water ſpouts and hurricanes, I ſhall add a deſcription of a hurricane in the Weſt Indies, from the *Account of the European Settlements in America*, part of which is tranſcribed from the Philoſophical Tranſactions. Both were evidently written without the moſt diſtant view to any philoſophical theory, and leaſt of all that of electricity; and yet thoſe who are diſpoſed to favour this hypotheſis may perceive ſeveral circumſtances, which tend to ſtrengthen it. I need not point them out.

"It is in the rainy ſeaſon, principally in the month of Auguſt, more rarely in July

* Remarks on Dr. Franklin's Letters, p. 348.

and

" and September, that they are assaulted by " *hurricanes*, the most terrible calamity to " which they are subject from the climate. " This destroys, at one stroke, the labour of " many years, and frustrates the most exalt- " ed hopes of the planter; and often just at " the moment when he thinks himself out of " the reach of fortune. It is a sudden and " violent storm of wind, rain, thunder, and " lightning; attended with a furious swelling " of the sea, and sometimes with an earth- " quake; in short, with every circumstance " which the elements can assemble that is ter- " rible and destructive.

" FIRST they see, as a prelude to the en- " suing havock, whole fields of sugar canes " whirled into the air, and scattered over the " face of the country. The strongest trees of " the forest are torn up by the roots, and " driven about like stubble. Their wind- " mills are swept away in a moment. Their " works, their fixtures, the ponderous copper " boilers and stills, of several hundred weight, " are wrenched from the ground, and batter- " ed to pieces. Their houses are no protec- " tion: the roofs are torn off at one blast, " whilst the rain, which in an hour rises five " feet, rushes in upon them with an irresistible " violence.

" THERE are signs, which the Indians of " these islands taught our planters, by which " they can prognosticate the approach of a " hurricane. It comes on either in the quar- " ters, or at the full or change of the moon.

If

"If it will come on at the full moon, you be-
"ing at the change, observe these signs:
"That day you will see the sky very turbu-
"lent. You will observe the sun more red
"than at other times. You will perceive a
"dead calm, and the hills clear of all those
"clouds and mists which usually hover about
"them. In the clefts of the earth, and in
"the wells, you will hear a hollow rumbling
"sound, like the rushing of a great wind. At
"night the stars seem much larger than usual,
"and surrounded with a sort of burs. The
"North-west sky has a black and menacing
"look, and the sea emits a strong smell, and
"rises into vast waves, often without any
"wind. The wind itself now forsakes its
"usual steady Easterly stream, and shifts
"about to the West; from whence it some-
"times blows, with intermissions, violent-
"ly and irregularly, for about two hours
"at a time. You have the same signs at the
"full of the moon. The moon itself is sur-
"rounded with a great bur, and sometimes
"the sun has the same appearance *."

THE first person who advanced that *earthquakes* were probably caused by electricity, was Dr. STUKELEY, upon occasion of the earthquakes at London, on February the 8th, and on March the 8th, 1749; and another which affected various other parts of England, the center being about Daventry in Northamp-

* Account of the European Settlements in America, Vol. ii. p. 96, &c. Phil. Transf. abridged, Vol. ii. p. 106.

tonshire,

tonshire, on the 30th of September 1750. The papers which the Doctor delivered to the Royal Society on these occasions, and which were read, March the 22d, 1749, and December the 6th, 1750, well deserve the attention of all philosophers and electricians. I shall here give the substance of both; only abridging, and differently arranging the materials of them.

THAT earthquakes are not owing to subterraneous winds, fires, vapours, or any thing that occasions an explosion, and heaves up the ground, he thought might easily be concluded from a variety of circumstances. In the first place, he thought there was no evidence of any remarkable cavernous structure of the earth; but that, on the contrary, there is rather reason to presume, that it is, in a great measure, solid; so as to leave little room for internal changes and fermentations within its substance; nor do coal-pits, he says, when on fire, ever produce any thing resembling an earthquake.

IN the second earthquake at London, there was no such thing as fire, vapour, smoke, smell, or an eruption of any kind observed, though the shock affected a circuit of thirty miles in diameter. This consideration alone, of the extent of surface shaken by an earthquake, he thought was sufficient to overthrow the supposition of its being owing to the expansion of any subterraneous vapours. For it could not possibly be imagined, that so immense a force, as could act upon that compass of

of ground inſtantaneouſly ſhould never break the ſurface of it, ſo as to be diſcoverable to the ſight or ſmell; when ſmall fire balls, burſting in the air, have inſtantly propagated a ſulphureous ſmell all around them, to the diſtance of ſeveral miles.

BESIDES, the operation of this great fermentation, and production of elaſtic vapours, &c. ought to be many days in continuance, and not inſtantaneous; and the evaporation of ſuch a quantity of inflammable matter would require a long ſpace of time.

HE thought that if vapours and ſubterraneous fermentations, exploſions, and eruptions were the cauſe of earthquakes, they would abſolutely ruin the whole ſyſtem of ſprings and fountains wherever they had once been: which is quite contrary to fact, even where they have been frequently repeated. Mentioning the great earthquake which happened A. D. 17, when no leſs than thirteen great cities of Aſia Minor were deſtroyed in one night, and which may be reckoned to have ſhaken a maſs of earth 300 miles in diameter, he aſks, How can we poſſibly conceive the action of any ſubterraneous vapours to produce ſuch an effect ſo inſtanteouſly? How came it to paſs, that the whole country of Aſia Minor was not at the ſame time deſtroyed, its mountains reverſed, its fountains and ſprings broken up, and ruined for ever, and the courſe of its rivers quite changed? Whereas, nothing ſuffered but the cities. There was no kind of altera-

alteration in the ſurface of the country, which, indeed, remains the ſame to this day.

To make the hypotheſis of ſubterraneous vapours, &c. being the cauſe of earthquakes the more improbable, he obſerves, that any ſubterraneous power, ſufficient to move a ſurface of earth thirty miles in diameter, as in the earthquakes which happened at London, muſt be lodged at leaſt fifteen or twenty miles below the ſurface of the earth, and therefore muſt move an inverted cone of ſolid earth, whoſe baſis is thirty miles in diameter, and axis fifteen or twenty miles; an effect which, he ſays, no natural power could produce.

UPON the ſame principle, the ſubterraneous cauſe of the earthquake in Aſia Minor muſt have moved a cone of earth of 300 miles in baſe, and 200 in the axis; which, he ſays, all the gun-powder which has ever been made ſince the invention of it would not have been able to ſtir, much leſs any vapours, which could be ſuppoſed to be generated ſo far below the ſurface.

IT is not upon the principles of any ſubterraneous exploſion that we can, in the leaſt, account for the manner in which ſhips, far from any land, are affected during an earthquake; which ſeem as if they ſtruck upon a rock, or as if ſomething thumped againſt their bottoms. Even the fiſhes are affected by an earthquake. The ſtroke, therefore, muſt be occaſioned by ſomething that could communicate motion with unſpeakably greater velocity than

than any heaving of the earth under the ſea, by the elaſticity of generated vapours. This could only produce a gradual ſwell, and could never give ſuch an impulſe to the water, as would make it feel like a ſtone.

COMPARING all theſe circumſtances, Dr. Stukeley ſays, he had always thought, that an earthquake was an electrical ſhock, of the ſame nature with thoſe which are now become familiar in electrical experiments. And this hypotheſis he thought was confirmed by the phenomena preceding and attending earthquakes, particularly thoſe which occaſioned this publication.

THE weather, for five or ſix months before the firſt of theſe earthquakes, had been dry and warm to an extraordinary degree, the wind generally South and South-Weſt, and that without rain; ſo that the earth muſt have been in a ſtate of electricity ready for that particular vibration in which electrification conſiſts. On this account, he obſerves, that the Northern regions of the world are but little ſubject to earthquakes in compariſon with the Southern, where the warmth and dryneſs of the air, ſo neceſſary to electricity, are common. All the flat country of Lincolnſhire before the earthquake in September, though, underneath it is a watery bog, yet, through the whole preceding ſummer and autumn (as they can have no natural ſprings in ſuch a level), the drought had been ſo great on the ſurface of the earth, that the inhabitants were obliged to drive their cattle ſeveral miles to

water.

water. This, he ſays, ſhows how fit the dry ſurface was for an electrical vibration; and alſo, which is of great importance, that earthquakes reach but very little below the ſurface of the earth.

Before the earthquake at London, all vegetables had been uncommonly forward. At the end of February, in that year, all ſorts of garden ſtuff, fruits, flowers, and trees were obſerved to be as forward as, in other years, about the middle of April; and electricity is well known to quicken vegetation.

The aurora borealis had been very frequent about the ſame time, and had been twice repeated juſt before the earthquake, of ſuch colours as had never been ſeen before. It had alſo removed to the South, contrary to what is common in England; ſo that ſome Italians, and people from other places where earthquakes are frequent, obſerving theſe lights, and the peculiar temperature of the air, did actually foretell the earthquake. For a fortnight before the earthquake in September, the weather was ſerene, mild, and calm; and, one evening, there was a deep red Aurora Borealis, covering the cope of heaven, very terrible to behold.

The whole year had been exceedingly remarkable for fire-balls, thunder, lightning, and coruſcations, almoſt throughout all England. Fire balls were more than once ſeen in Ireland and Lincolnſhire, and particularly obſerved. And all theſe kinds of meteors, the Doctor ſays, are rightly judged to proceed

ceed from the electrical ſtate of the atmoſphere.

In theſe previous circumſtances of the ſtate of the earth and air, nothing, he ſays, is wanting to produce the wonderful effect of an earthquake, but the touch of ſome non-electric body, which muſt neceſſarily be had *ab extra*, from the region of the air, or atmoſphere. Hence, he infers that, if a non-electric cloud diſcharge its contents upon any part of the earth in that highly electrical ſtate, an earthquake muſt neceſſarily enſue. As the diſcharge from an excited tube produces a commotion in the human body, ſo the diſcharge of electric matter from the compaſs of many miles of ſolid earth muſt needs be an earthquake, and the ſnap from the contact be the horrid uncouth noiſe attending it.

The Doctor had been informed, by thoſe who were up and abroad the night preceding the earthquake, and early in the morning, that coruſcations in the air were extremely frequent; and that, a little before the earthquake, a large and black cloud ſuddenly covered the atmoſphere, which probably occaſioned the ſhock, by the diſcharge of a ſhower. Dr. Childrey, he ſays, obſerves, that earthquakes are always preceded by rain, and ſudden tempeſts of rain in times of great drought.

A sound was obſerved to roll from the river Thames towards Temple Bar, before the houſes ceaſed to nod, juſt as the electrical ſnap precedes the ſhock. This noiſe, an ob-

ſerver ſaid, was much greater than any he had ever heard. Others, who write upon earthquakes, commonly obſerve, that the noiſe precedes the ſhock: whereas it muſt have been quite the contrary, if the concuſſion had depended upon a ſubterraneous eruption. This noiſe attending earthquakes, the Doctor thought, could not be accounted for, but upon the principles of electricity. The earthquake in September was attended with a ruſhing noiſe, as if houſes were falling, and people, in ſome places, were ſo univerſally frighted, as to run out of their houſes, imagining that their own, and thoſe of their neighbours were tumbling on their heads. In ſome villages, the people, being at divine ſervice, were much alarmed with the noiſe; which they ſaid, beyond all compariſon, exceeded all the thunder they had ever heard.

THE flames and ſulphureous ſmells, which are ſometimes obſerved during earthquakes, the Doctor thought were more eaſily accounted for, from the ſuppoſition of their being electrical phenomena, than from their being occaſioned by the eruption of any thing from the bowels of the earth.

THE impreſſion made by an earthquake upon land and water, to the greateſt diſtances is, as was obſerved before, inſtantaneous, which could only be effected by electricity. In the earthquake in September, the concuſſion was felt through a ſpace of 100 miles in length, and forty in breadth; and, as far, as could be judged, at the ſame inſtant of time.

That

That this tract of ground, which amounted to 4000 square miles in surface, should be thrown into such agitation in a moment, is such a prodigy, the Doctor says, as we could never believe, or conceive, did we not know it to be fact from our senses. But if we seek the solution of it, we cannot think any natural power equal to it but that of electricity, which acknowledges no sensible transition of time, no bounds.

THE little damage generally done by earthquakes, the Doctor thought to be an argument of their being occasioned by a simple vibration, or tremulous motion of the surface of the earth, by an electrical snap. This vibration, he says, impressed on the water, meeting with the solid bottoms of ships and lighters, occasions that thump which is said to be felt by them: yet, of the millions of ordinary houses, over which it passed, not one fell. A consideration which sufficiently points out what sort of a motion this was not; also what sort of a motion it was, and whence derived; not a convulsion in the bowels of the earth, but an uniform vibration along its surface, like that of a musical string, or what we put a drinking-glass into, by rubbing one's finger on the edge; which yet, being brought to a certain pitch, breaks the glass; undoubtedly, he adds, an electrical repulsion of its parts.

THAT earthquakes are electrical phenomena, is farther evident, he says, from their chiefly affecting the sea-coast, places along rivers, and, I may add, eminences. The

earthquake in September ſpread moſtly to the North and South, which the Doctor ſays is the direction of the Spalding river, whereby it was conveyed to the ſea ſhore, where it was particularly ſenſible; thence up Boſton channel, and ſo up Boſton river to Lincoln. The greateſt part of this earthquake diſplayed its effects along, and between the two rivers Welland and Avon, and that from their ſources down to their mouths. It likewiſe reached the river Witham, which directed the electrical ſtream that way alſo to Lincoln; for which reaſon, meeting the ſame coming from Boſton, it was moſt ſenſibly felt there. It reached, likewiſe, to the Trent at Nottingham, which conveyed it to Newark.

THE firſt electrical ſtroke in this earthquake ſeemed to the Doctor to have been made on the high ground about Daventry, in Northamptonſhire. From thence it deſcended chiefly Eaſtward, and along the river Welland, from Harborough to Stamford, Spalding, and the ſea; and along the rivers Avon and Nen to Northampton, Peterborough, Wiſbich, and the ſea. It ſpread itſelf all over the vaſt level of the iſle of Ely, promoted by a great number of canals, natural and artificial, made for draining that country. It was ſtill conducted Eaſtward, by Mildenhall river in Suffolk, to Bury, and the parts adjacent. All theſe circumſtances duly conſidered were to him a confirmation of the doctrine he advanced on this ſubject.

LASTLY,

Lastly, the Doctor adds, as a farther argument in favour of his hypothesis, that pains in the back, rheumatic, hysteric, and nervous cases; head-aches, cholics, &c. were felt by many people of weak constitutions, for a day or two after the earthquake; just as they would after electrification; and, to some, these disorders proved fatal.

In what manner the earth and atmosphere are put into that electrical and vibratory state, which prepares them to give or receive that snap and shock, which we call an earthquake, and whence it is that this electric matter comes, the Doctor does not pretend to say, but thinks it as difficult to account for as magnetism, gravitation, muscular motion, and many other secrets in nature *.

To these observations of Dr. Stukeley, I shall add some circumstances which were observed by Dr. Hales, in the earthquake at London, on March the 8th, 1749, as tending to strengthen the hypothesis of its being caused by electricity; though the Doctor, who relates them, thought that the electric appearances were only occasioned by the great agitation which the electric fluid was put into, by the shock of so great a mass of the earth.

At the time of the earthquake, about twenty minutes before six in the morning, the Doctor, being awake in bed, on a ground floor, at a house near the church of St. Mar-

* Phil. Transf. abridged, Vol. x. p. 526. 535. and p. 541. 551.

 tin's

tin's in the Fields, very ſenſibly felt his bed heave, and heard an obſcure ruſhing noiſe in the houſe, which ended in a loud exploſion up in the air, like that of a ſmall cannon. The whole duration, from the beginning to the end, ſeeming to be about four ſeconds.

THIS great noiſe, the Doctor conjectured, was owing to the ruſhing, or ſudden expanſion of the electric fluid at the top of St. Martin's ſpire, where all the electric effluvia, which aſcended along the large body of the tower, being ſtrongly condenſed, and accelerated at the point of the weathercock, as they ruſhed off, made ſo much the louder expanſive exploſion.

THE Doctor farther ſays, that the ſoldiers, who were upon duty in St. James's park, and other perſons who were then up, ſaw a blackiſh cloud, and a conſiderable lightning, juſt before the earthquake began *.

MR. HARTMAN is of opinion that electricity is the cauſe of earthquakes, and gives a ſuccinct enumeration of all the circumſtances which favour this hypotheſis †.

MY reader, who has ſeen to how great an extent Signior Beccaria has already carried the principles of electricity, will have no doubt but that he ſuppoſes *earthquakes* to be derived from that cauſe. And indeed, without any knowledge of what Dr. Stukeley had done, he did ſuppoſe them to be electrical phenomena; but, contrary to the Doctor, imagined the

* Phil. Tranſ. abridged, Vol. x. p. 540, 541.
† Abhandlung, p. 148.

electric matter which occasioned them to be lodged deep in the bowels of the earth, agreeable to his hypothesis concerning the origin of lightning.

It is certain that if Signior Beccaria's account of the origin of thunder clouds be admitted, there will be little difficulty in admitting farther, that *earthquakes* are to be reckoned among the effects of electricity. For if the equilibrium of the electric matter can, by any means, be lost in the bowels of the earth; so that the best method of restoring it shall be by the fluid bursting its way into the air, and traversing several miles of the atmosphere to come to the place where it is wanted; it may easily be imagined, that violent concussions may be given to the earth, by the sudden passage of this powerful agent. And several circumstances attending earthquakes he thought rendered this hypothesis by no means improbable.

Volcanos are known to have a near connection with earthquakes; and flashes of light, exactly resembling lightning, have frequently been seen to rush from the top of Mount Vesuvius, at the time that ashes and other light matter have been carried out of it into the air, and been dispersed uniformly over a large tract of country. Of these he produces a great number of instances, from the best authority *.

* Lettere dell' elettricismo, p. 226. 362, &c.

A RUMBLING noiſe, like thunder, is generally heard during an earthquake. At ſuch times, alſo, flaſhes of light have been ſeen riſing out of the ground, and darting up into the air. Real lightning hath ſometimes occaſioned ſmall ſhakings of the earth, at leaſt has been attended by them. But the ſtrongeſt circumſtance of reſemblance which he obſerved is the ſame that Dr. Stukeley lays ſo much ſtreſs on, viz. the amazing ſwiftneſs with which the earth is ſhaken in earthquakes. An earthquake, ſays he, is by no means a gradual heaving, as we might have expected from other cauſes, but an inſtantaneous concuſſion, ſo that the fluidity of the water is no ſecurity againſt the blow. The very ſhips, many leagues off the coaſt, feel as if they ſtruck againſt a rock.

THIS admirable philoſopher, having imitated all the great phenomena of natural electricity in his own room, doth not let the earthquake eſcape him. He ſays, that if two pieces of glaſs, incloſing a thin piece of metal, be held in the hand, while a large ſhock is ſent through them, a ſtrong vibration, or concuſſion will be felt; which ſometimes, as in Dr. Franklin's experiments, breaks them to pieces.

SIGNIOR BECCARIA thinks, that there are traces of electrical operations in the earthquake, that happened at Julian's attempt to rebuild the temple of Jeruſalem *.

* *Lettere dell' elettriciſmo*, p. 363.

THAT

THAT the electric fluid is ſometimes collected in the bowels of the earth, he thought was probable from the appearance of *ignes fatui* in mines, which ſometimes happens, and is very probably an electrical phenomenon *.

WHICH of theſe two philoſophers have advanced the more probable opinion concerning the ſeat of the electric matter which occaſions earthquakes, I ſhall not pretend to decide. I ſhall only obſerve that, perhaps, a more probable general hypotheſis than either of them may be formed out of them both. Suppoſe the electric matter to be, ſome way or other, accumulated on one part of the ſurface of the earth, and, on account of the dryneſs of the ſeaſon, not eaſily to diffuſe itſelf; it may, as Signior Beccaria ſuppoſes, force itſelf a way into the higher regions of the air, forming clouds in its paſſage out of the vapours which float in the atmoſphere, and occaſion a ſudden ſhower, which may farther promote the paſſage of the fluid. The whole ſurface, thus unloaded, will receive a concuſſion, like any other conducting ſubſtance on parting with, or receiving a quantity of the electric fluid. The ruſhing noiſe will, likewiſe, ſweep over the whole extent of the country. And, upon this ſuppoſition, alſo, the fluid, in its diſcharge from the country, will naturally follow the courſe of the rivers, and alſo take the

* Dell' elettriciſmo artificiale e naturale, p. 223.

advantage

advantage of any eminences, to facilitate its aſcent into the higher regions of the air.

I SHALL cloſe this account of the theory of lightning and other phenomena of the atmoſphere, with an enumeration of the principal appearances of natural electricity obſerved by the ancients, and which were never underſtood before the diſcovery of Dr. Franklin. It will be very eaſy for me to do this, as I find them already collected to my hands by Dr. Watſon *.

A LUMINOUS appearance, which muſt have been of an electrical nature, is mentioned by Plutarch in his life of Lyſander. He conſidered it as a meteor.

PLINY, in his ſecond book of Natural Hiſtory, calls thoſe appearances *ſtars*, and tells us, that they ſettled not only upon the maſts, and other parts of ſhips, but alſo upon men's heads. *Exſiſtunt*, ſays that hiſtorian, *ſtellæ et in mari terriſque. Vidi nocturnis militum vigiliis inhærere pilis pro vallo fulgorem effigie ea: et antennis navigantium aliiſque navium partibus, ceu vocali quodam ſono inſiſtunt, ut volucres, ſedem ex ſede mutantes.——Geminæ autem ſalutares et proſperi curſus prænunciæ; quarum adventu, fugari diram illam ac minacem appellatamque Helenam ferunt. Et ob id Polluci et Caſtori id numen aſſignant, eoſque in mari deos invocant. Hominum quoque capiti veſpertinis horis, magno præſagio circumfulgent.*

* Phil. Tranſ. Vol. xlviii. pt. i. p. 210.

But,

But, adds he, theſe things are *incerta ratione et in naturæ majeſtate abdita.*

"STARS make their appearance both at "land and ſea. I have ſeen a light in that "form on the ſpears of ſoldiers, keeping "watch by night upon the ramparts. They "are ſeen alſo on the ſail-yards, and other "parts of ſhips, making an audible ſound, "and frequently changing their places. Two "of theſe lights forebode good weather, and "a proſperous voyage; and drive away *one* "that appears ſingle, and wears a threatening "aſpect. This the ſailors call Helen, but "the *two* they call Caſtor and Pollux, and "invoke them as Gods. Theſe lights do "ſometimes, about the evening, reſt on "men's heads, and are a great and good "omen. But theſe are among the awful "myſteries of nature."

SENECA in his Natural Queſtions, chap. i. takes notice of the ſame phenomenon. *Gylippo, Syracuſas petenti viſa eſt ſtella ſupra ipſam lancem conſtitiſſe. In Romanorum caſtris viſa ſunt ardere pila, ignibus ſcilicet in illis delapſis.*

"A STAR ſettled on the lance of Gylip-"pus, as he was ſailing to Syracuſe: and "ſpears have ſeemed to be on fire in the Ro-"man camp."

IN Cæſar, de Bello Africano, cap. vi. edit. Amſtel. 1686, we find them attending a violent ſtorm. *Per id tempus fere Cæſaris exercitui res accidit incredibilis auditu; nempe Vir-*

Virgiliarum ſigno confecto, circiter vigilia ſecunda noctis, nimbus cum ſaxea grandine ſubito eſt coortus ingens. Eadem nocte legionis V. pilorum cacumina ſua ſponte arſerunt.

"About that time, there was a very extra-"ordinary appearance in the army of Cæſar. "In the month of February, about the ſecond "watch of the night, there ſuddenly aroſe a "thick cloud, followed by a ſhower of ſtones; "and the ſame night, the points of the "ſpears belonging to the fifth legion ſeemed "to take fire."

LIVY, cap. xxxii. mentions two ſimilar facts. *In Sicilia militibus aliquot ſpicula, in Sardinia muro circumeunti vigilias equiti, ſcipionem, quem in manu tenuerat, arſiſſe; et litora crebris ignibus fulſiſſe.*

"THE ſpears of ſome ſoldiers in Sicily, "and a walking-ſtick, which a horſeman in "Sardinia was holding in his hand, ſeemed to "be on fire. The ſhores were alſo luminous "with frequent fires."

THESE appearances are called, both by the French and Spaniards, inhabiting the coaſts of the Mediterranean, St. Helme's, or St. Telme's fires; by the Italians the fires of St. Peter, and St. Nicholas; and are frequently taken notice of by the writers of voyages.

IF ſome late accounts from France, adds the Doctor, are to be depended upon, this phenomenon has been obſerved at Plauzet for time immemorial, and Mr. Binon, the Curé

Curé of the place ſays, that for twenty-ſeven years, which he has reſided there, in great ſtorms accompanied with black clouds, and frequent lightning, the three pointed extremities of the of the croſs of the ſteeple of that place appeared ſurrounded with a body of flame; and that when this phenomenon has been ſeen, the ſtorm was no longer to be dreaded, and calm weather returned ſoon after.

Modern hiſtory furniſhes a great number of examples of flames appearing at the extremities of pointed metallic bodies projecting into the air. Little notice was taken of theſe, while the cauſe of them was unknown; but ſince their near affinity with lightning has been diſcovered, they have been more attended to, and collected.

SECTION XIII.

OBSERVATIONS ON THE USE OF METALLIC CONDUCTORS TO SECURE BUILDINGS, &C. FROM THE EFFECTS OF LIGHTNING.

THE former sections of this period relate chiefly to the theory of electricity. In the two next I shall consider what has been done towards reducing this science into practice. And, in the first place, I shall recite the observations that have been made respecting the use of metallic conductors, to secure buildings from lightning, as having the nearest connection with the subject of the sections immediately preceding.

DR. FRANKLIN's proposal to preserve buildings from the dreadful effects of lightning was by no means a matter of mere theory. Several striking facts, which occurred within the period of which I am treating, demonstrate its utility.

INNUMERABLE observations show how readily metallic rods actually conduct lightning, and how small a substance of metal is sufficient to discharge great quantities of it. Mr. Calendrini, who afterwards applied to Dr. Watson, to be informed of the best methods of securing powder magazines, says that he himself was an eye-witness of the effect of a flash of lightning, where he observed it had struck the wire of a bell, and had been com-

pletely

pletely conducted by it, from one room of a house to another, through a very small hole in the partition. This observation was prior to the discoveries of Dr. Franklin, but was recollected and recorded afterwards *.

Dr. Franklin himself, in a letter to Mr. Dalibard, dated Philadelphia, June the 29th, 1755, relating what had been shown him of the effects of lightning on the church of Newbury in New England, observes, that a wire not bigger than a common knitting needle, did in fact conduct a flash of lightning, without injuring any part of the building as far as it went, though the force of it was so great, that from the termination of the wire down to the ground, the steeple was exceedingly rent and damaged, some of the stones, even in the foundation, being torn out, and thrown to the distance of twenty or thirty feet. No part of the wire, however, could be found, except about two inches at each extremity, the rest being exploded, and its particles dissipated in smoke and air, as the Doctor says, like gunpowder by a common fire. It had only left a black smutty track upon the plaister of the wall along which it ran, three or four inches broad, darkest in the middle, and fainter towards the edges. From the circumstances of this fact it was very evident, that, had the wire been continued to the foot of the building, the whole shock would have been conducted without the least

* Phil. Transf. Vol. liv. pt. i. p. 205.

injury

injury to it, though the wire would have been deſtroyed *.

But the moſt complete demonſtration of the real uſe of Dr. Franklin's method of ſecuring buildings from the effects of lightning, is Mr. Kinnerſley's account of what happened to the houſe of Mr. Weſt, a merchant of Philadelphia in Penſilvania, which was guarded by an apparatus conſtructed according to the directions of Dr. Franklin. It conſiſted of an iron rod, which extended about nine feet and an half above a ſtack of chimnies, to which it was fixed. It was more than half an inch in diameter in the thickeſt part, and went tapering to the upper end, in which there was a hole that received a braſs wire about three lines thick and ten inches long, terminating in a very acute point: the lower part of the apparatus joined to an iron ſtake, driven four or five feet into the ground.

Mr. West judging, by the dreadful flaſh of lightning and inſtant crack of thunder, that the conductor had been ſtruck, got it examined; when it appeared, that the top of the pointed rod was melted, and the ſmall braſs wire reduced to ſeven inches and a half in length, with its top very blunt. The ſlendereſt part of the wire he ſuſpected, had been diſſipated in ſmoke; but ſome of it, where the wire was a little thicker, being only melted by the lightning, ſunk down (while in a fluid ſtate) and formed a rough irregular cap, lower

* Phil. Tranſ. Vol. xlix. pt. i. p. 309.

on

on one ſide than on the other, round the upper end of what remained, and became intimately united with it. It is remarkable, that, notwithſtanding the iron ſtake, in which the apparatus terminated, was driven three or four feet into the ground, yet the earth did not conduct the lightning ſo faſt, but that, in thunder ſtorms the lightning would be ſeen diffuſed near the ſtake two or three yards over the pavement, though at that time very wet with rain *.

In order to ſecure ſhips from ſuſtaining damage by lightning, Dr. Watſon, in a letter to Lord Anſon, read at the Royal Society, December the 16th, 1762, adviſes, that a rod of copper, about the thickneſs of a gooſe quill, be connected with the ſpindles and iron work of the maſt; and, being continued down to the deck, be from thence, in any convenient direction, ſo diſpoſed, as always to touch the ſea water †.

With reſpect to powder magazines, Dr. Watſon adviſed Mr. Calandrini above mentioned, that the apparatus to conduct the lightning from them be detached from the buildings themſelves, and conveyed to the next water.

What lately happened to St. Bride's church in London is a ſufficient proof of the utility of metallic conductors for lightning. Dr. Watſon, who publiſhed an account of this fact in the Philoſophical Tranſactions, ob-

* Phil. Tranſ. Vol. liii. pt. i. p. 96.
† Ibid. Vol. lii. pt. i. p. 633.

 ſerves,

ſerves, that the lightning firſt took a weather-cock, which was fixed at the top of the ſteeple; and was conducted without injuring the metal, or any thing elſe, as low as where the large iron bar or ſpindle which ſupported it (and which came down ſeveral feet into the top of the ſteeple) terminated. There, the metallic communication ceaſing, part of the lightning exploded, cracked, and ſhattered the obeliſk, which terminated the ſpire of the ſteeple, in its whole diameter, and threw off at that place ſeveral large pieces of Portland ſtone, of which the ſteeple was built. Here it likewiſe removed a ſtone from its place, but not far enough to be thrown down. From thence the lightning ſeemed to have ruſhed upon two horizontal iron bars, which were placed within the building croſs each other, to give additional ſtrength to the obeliſk, almoſt at the baſe of it, and not much above the upper ſtory. At the end of one of theſe iron bars, on the Eaſt and North-Eaſt ſide, it exploded again, and threw off a conſiderable quantity of ſtone. Almoſt all the damage done to the ſteeple, except near the top, was confined to the Eaſt and North-Eaſt ſide, and generally, where the ends of the iron bars had been inſerted into the ſtone, or placed under it; and, in ſome places, by its violence in the ſtone, its paſſage might be traced from one iron bar to another.

It is very remarkable, that, to leſſen the quantity of ſtone in this beautiful ſteeple, cramps of iron had been employed in ſeveral

parts

parts of it; and upon these, stones of no great thickness had been placed; both by way of ornament, and to cover the cramped joint. In several places these stones had, on account of their covering the iron, been quite blown off, and thrown away. A great number of stones, some of them large ones, were thrown from the steeple, three of which fell upon the roof of the church, and did great damage to it; and one of them broke through the large timbers which formed the roof, and lodged in the gallery.

Upon the whole, the steeple was found, on a survey, to be so much damaged in several of its parts, that eighty-five feet were taken down, in order to restore it substantially; and the manner in which this steeple was damaged completely indicated, as Dr. Watson observes, the great danger of insulated masses of metal from lightning; and, on the contrary, evinced the utility and importance of masses of metal continued, and properly conducted, in defending them from its direful effects. The iron and lead employed in this steeple, in order to strengthen and preserve it, did almost occasion its destruction; though, after it was struck by the lightning, had it not been for these materials keeping the remaining parts together, a great part of the steeple must have fallen.

This building suffered the more, on account of the thunder storm having been preceded by several very warm days. The nights had scarce furnished any dew, the air

was quite dry, and in a ſtate perfectly unfit to part with its highly accumulated electricity, without violent efforts. This great dryneſs had made the ſtones of St. Bride's ſteeple, and all other buildings under the like circumſtances, far leſs fit, than if they had been in a moiſt ſtate, to conduct the lightning, and prevent the miſchief. For, though the thunder ſtorm ended in a heavy ſhower of rain, none, except a few very large drops, fell till after the church was ſtruck. And Dr. Watſon had no doubt, but that the ſucceeding rain prevented many accidents of a ſimilar kind, by bringing down, with every drop of it, part of the electric matter, and thereby reſtoring the equilibrium between the earth and clouds.

IT is frequently obſerved, he ſays, that, in attending to the apparatus for collecting the electricity of the clouds, though the ſky is much darkened, and there have been ſeveral claps of thunder, at no great diſtance, yet the apparatus will ſcarcely be affected by it; but that, as ſoon as the rain begins and falls upon ſo much of the apparatus as is placed in the open air, the bells belonging to it will ring, and the electrical ſnaps ſucceed each other in a very extraordinary manner. This, as he obſerves, demonſtrates, that every drop of rain brings down part of the electric matter of a thunder cloud and diſſipates it in the earth and water, thereby preventing the miſchiefs of its violent and ſudden exploſion. Hence when the heavens have a menacing appearance, a ſhower of rain is much to be wiſhed for.

From all theſe conſiderations, Dr. Watſon had no doubt, but that the miſchief done to St. Bride's ſteeple was owing to the efforts of the lightning, after it had poſſeſſed the apparatus of the weathercock, endeavouring to force itſelf a paſſage from thence to the iron work employed in the ſteeple. As this muſt be done *per ſaltum*, as he expreſſes it, there being no regular metallic communication, it was no wonder, when its force was vehement, that it rent every thing which was not metallic that obſtructed its eaſy paſſage; and that, in this particular inſtance, the ravages increaſed, as the lightning, to a certain diſtance, came down the ſteeple.

The Doctor adviſes that, in order to have ocular demonſtration when theſe metallic conductors do really diſcharge the lightning, they be diſcontinued for an inch or two, in ſome place convenient for obſervation; in which caſe the fire will be ſeen to jump from one extremity of the wire to the other. If any danger be apprehended from this diſcontinuance of the metallic conductor, he ſays that a looſe chain may be ready to hang on, and complete the communication *.

Mr. Delaval, who alſo gives an account of the ſame accident, obſerved, that, in every part of the building that was damaged, the lightning had acted as an elaſtic fluid, endeavouring to expand itſelf where it was accumulated in the metal; and that the effects

* Phil. Tranſ. Vol. liv. p. 201, &c.

were exactly ſimilar to thoſe which would have been produced by gunpowder pent up in the ſame places, and exploded.

IN the ſame paper Mr. Delaval gives it as his opinion, that a wire, or very ſmall rod of metal, did not ſeem to have been a canal ſufficiently large to conduct ſo great a quantity of lightning as ſtruck this ſteeple; eſpecially if any part of it, or of the metal communicating with it, was incloſed in the ſtone work, in which caſe, he thought, the application of it would tend to increaſe its bad effects, by conducting it to parts of the building which it might otherwiſe not have reached.

UPON the whole, he thought that a conductor of metal, leſs than ſix or eight inches in breadth, and a quarter of an inch in thickneſs (or an equal quantity of metal in any other form that might be found more convenient) cannot with ſafety be depended on, where buildings are expoſed to the reception of a great quantity of lightning *.

MR. WILSON, in a paper written upon the ſame occaſion, adviſes, that pointed bars or rods of metal be avoided in all conductors of lightning.

As the lightning, he ſays, muſt viſit us ſome way or other, from neceſſity, there can be no reaſon to invite it at all; but, on the contrary, when it happens to attack our buildings, we ought only ſo to contrive our apparatus, as to be able to carry the lightning

* Phil. Tranſ. Vol. liv. p. 2;4.

away

away again, by ſuch ſuitable conductors, as will very little, if at all, promote any increaſe of its quantity.

To attain this deſirable end, in ſome degree at leaſt, he propoſes, that the ſeveral buildings remain as they are at the top; that is, without having any metal above them, either pointed or not, by way of conductor; but that on the inſide of the higheſt part of the building, within a foot or two of the top, a rounded bar of metal be fixed, and continued down along the ſide of the wall, to any kind of moiſture in the ground *.

SIGNIOR BECCARIA whoſe obſervations and experience with reſpect to lightning give a weight to his opinion ſuperior to that of any other man whatever, ſeems to think very differently from Mr. Wilſon on this ſubject. He ſays that no metallic apparatus can attract more lightning than it can conduct. And ſo far is he from thinking one conductor, rounded at the top, and a foot or two under the roof ſufficient; that if the building be of any extent, he adviſes to have ſeveral of the uſual form; that is, pointed, and higher than the building. One conductor he thought ſufficient for one tower, ſteeple, or ſhip; but he thought, two neceſſary for the wing of a building 200 feet long, one at each extremity; three for two ſuch wings, the third being fixed in the middle; and four for a ſquare palace of the ſame front, one at each corner †.

* Phil. Tranſ. Vol. liv. p. 249.
† Lettere dell' elettriciſmo, p. 278.

My readers at a diſtance from London will hardly believe me, when I inform them, that the elegant ſpire which has been the ſubject of a great part of this ſection, and which has been twice damaged by lightning (for it is now very probable, that a damage it received in the year 1750, was owing to the ſame cauſe) is now repaired, without any metallic conductor, to guard it in caſe of a third ſtroke.

SECTION XIV.

Of MEDICAL ELECTRICITY

THE ſubject of medical electricity falls almoſt wholly within the period of which I am now treating. For, though ſome effects of electricity upon animal bodies had been noted by the Abbé Nollet, and a few diſeaſed perſons had ſaid they had received benefit from being electrified; yet very little had been done this way, and phyſicians had ſcarcely attended to it, till within this period; whereas electricity is now become a conſiderable article in the *materia medica*.

The firſt account I have met with of the application of electricity to medical purpoſes is of Mr. C. Kratzenſtein, profeſſor of medicine at Halle; who, in the year 1744, cured a woman of a contracted little finger in a quarter of an hour. He alſo ſo far relieved a perſon who had two lame fingers, by once electrifying them, that he could play upon the

the harpsicord, which he had before been disabled from doing. He also observed, that a man's pulse, which had beat eighty in a second before he was electrified, immediately after beat eighty-eight, and was presently increased to ninety-six *.

There is, another celebrated instance of the cure of a palsy before this period; which is that performed by Mr. Jallabert, professor of philosophy and mathematics at Geneva, on a lock-smith of the age of fifty-two †, whose right arm had been paralytic fifteen years, occasioned by a blow of a hammer. He was brought to Mr. Jallabert on the 26th of December 1747, and was almost completely cured by the 28th of February 1748. In this interval he was frequently electrified, sparks being taken from the arm, and sometimes the electric shock sent through it ‡. Mr. Jallabert's own account of this cure is very circumstantial. But it appears from the Abbé Nollet's account of his second journey to Italy, that this person relapsed to the condition in which Mr. Jallabert found him. See the French translation of this book, vol. ii. p. 396.

The report of this cure performed at Geneva engaged Mr. Sauvages of the Academy in Montpelier to attempt the cure of paralytics, in which he had considerable success. In one case it occasioned a salivation, and in

* Dantzick Memoirs, Vol. i. p. 294.
† Jallabert's Experiences, 143.
‡ Histoire, pt. iii. p 36.

another

another a profuſe ſweat. Many paralytics, however, were electrified without any ſucceſs. Indeed the prodigious concourſe of patients of all kinds, which the report of theſe cures brought together, was ſo great, that few of them could be electrified, except very imperfectly. For two or three months together, twenty different patients were electrified every day. It is not ſurpriſing to find, that the neighbouring populace conſidered theſe cures as an affair of witchcraft, and that the operators were obliged to have recourſe to their prieſts to undeceive them *. In the courſe of theſe experiments it was found, by very accurate obſervations made with a pendulum, that electrification increaſes the circulation of the blood about one ſixth.

One of the firſt who attended to electricity in a medical way was Dr. Bohadtch a Bohemian; who, in a treatiſe upon medical electricity, communicated to the Royal Society, gave it as his opinion, after the reſult of much experience, that of all diſtempers the *hemiplegia* ſeemed to be the moſt proper object of electricity. He alſo thought it might be of uſe in intermitting fevers †.

The palſy having happened to be the firſt diſorder in which electricity gave relief, there was a conſiderable number of caſes publiſhed pretty early, in which paralytics were ſaid to have found benefit from this new method of treatment. In the year 1757, Mr. Patric

* Hiſtoire, p. 97. † Phil. Tranſ. Vol. xlvii. p. 351.

Brydone

Brydone performed a complete cure of a hemiplegia, and, indeed, an almoſt univerſal paralytic affection, in about three days. The patient was a woman, aged thirty-three, and the palſy was of about two years continuance *. And John Godfrey Teſke, very nearly cured a young man, of the age of twenty, of a paralytic arm, of which he had not had the leaſt uſe from the age of five years †.

THE Abbé Nollet's experiments upon paralytics had no permanent good effect ‡. He obſerves, however, that, during fifteen or ſixteen years that he had electrified all ſorts of perſons, he had known no one bad effect to have ariſen from it to any of them §.

DR. HART, in a letter to Dr. Watſon, dated Salop, March the 20th, 1756, mentions a cure performed by electricity upon a woman of twenty-three years of age, whoſe hand and wriſt had for ſome time been rendered uſeleſs by a violent contraction of the muſcles. She was not ſenſible of the firſt ſhock that was given her; but, as the ſhocks were repeated, the ſenſation increaſed, till ſhe was perfectly well. She was alſo cured a ſecond time, after a relapſe occaſioned by a cold ‖.

BUT perhaps the moſt remarkable caſe that has yet occurred of the uſe of electricity in curing a diſorder of this kind, and indeed of any that is incident to the human body was

* Phil. Tranſ. Vol. l. pt. i. p. 392.
† Ibid. Vol li. pt. i. p. 179.
‡ Recherches, p. 412. § Ibid. p. 416.
‖ Phil. Tranſ. Vol. xlix. pt. ii. p. 558.

of

of that dreadful disorder, an universal *tetanus*. It is related by Dr. Watson in the Philosophical Transactions; and the account was read at the Royal Society the 10th of February 1763. The patient was a girl belonging to the Foundling hospital, about seven years of age, who was first seized with a disorder occasioned by the worms, and at length by an universal rigidity of her muscles; so that her whole body felt more like that of a dead animal than a living one. She had continued in this dismal condition above a month, and about the middle of November 1762, after all the usual medicines had failed, Dr. Watson began to electrify her; and continued to do it by intervals, till the end of January following; when every muscle of her body was perfectly flexible, and subservient to her will, so that she could not only stand upright, but could walk, and even run like other children of her age *.

DR. EDWARD SPRY relates a complete cure which he made of a locked jaw and paralysis, in the case of a girl of eighteen years of age. Small shocks were given to the muscles particularly affected †.

THAT electricity may he hurtful, and even in some cases in which analogy would lead us to promise ourselves it might be of use, is evident from many cases, and particularly from one related by Dr. Hart of Shrewsbury, in a letter to Dr. Watson, which was read at the Royal Society, November the 14th, 1754.

* Phil. Transf. Vol. liii. p. 10. † Ibid. Vol. lvii. p. 88.

A YOUNG

A YOUNG girl about ſixteen, whoſe right arm was paralytic, and greatly waſted in compariſon of the other, on being electrified twice, became univerſally paralytic, and remained ſo above a fortnight; when the new palſy was removed by proper medicines, though the firſt diſeaſed arm remained as before.

However Dr. Hart, notwithſtanding this bad accident, had a mind to try electricity again. The girl ſubmitted to it, but after having been electrified about three or four days, ſhe became a ſecond time univerſally paralytic, and even loſt her voice, and the uſe of her tongue, ſo that it was with great difficulty ſhe could ſwallow. She was relieved of this additional palſy a ſecond time by a proper courſe of medicines, continued about four months; but was diſcharged out of the hoſpital as incurable of her firſt palſy. It is ſaid that the Doctor would have tried electricity a third time; but the girl, being more nearly concerned in the experiment than her phyſician, thought proper to decline it *.

DR. FRANKLIN's account of the effects of electricity, in the manner in which he applied it, is by no means favourable to its uſe in ſuch caſes. He ſays, in a letter to Sir John Pringle, read at the Royal Society, January the 12th, 1758, that ſome years before, when the news-papers made mention of great cures performed in Italy and Germany by electri-

* Phil. Tranſ. Vol. xlviii. pt. ii. p. 785.

city, a number of paralytics were brought to him, from different parts of Penfilvania and the neighbouring provinces, to be electrified, and that he performed the operation at their requeft. His method was, firft to place the patient in a chair, or upon an electrical ftool, and draw a number of large ftrong fparks from all parts of the affected limb or fide. He then fully charged two fix-gallon glafs jars, and fent the united fhock of them through the affected limb or limbs, repeating the ftroke commonly three times each day.

The firft thing he obferved was an immediate greater fenfible warmth in the affected limbs, which had received the ftroke, than in the others; and the next morning the patients ufually faid, that, in the night, they had felt a prickling fenfation in the flefh of the paralytic limbs; and would fometimes fhow a number of fmall red fpots, which they fuppofed were occafioned by thofe prickings. The limbs too were found more capable of voluntary motion, and feemed to receive ftrength. A man, for inftance, who could not, the firft day, lift his lame hand from off his knee, would the next day raife it four or five inches; the third day higher; and on the fifth was able, but with a feeble languid motion, to take off his hat. Thefe appearances, the Doctor fays, gave great fpirits to the patients, and made them hope for a perfect cure; but he did not remember that he ever faw any amendment after the fifth day; which

8 the

the patients perceiving, and finding the ſhocks pretty ſevere, became diſcouraged, went home, and in a ſhort time relapſed; ſo that he never knew any permanent advantage from electricity in palſies.

PERHAPS, ſays he, ſome permanent advantage might be obtained, if the electric ſhocks had been accompanied with proper medicine and regimen, under the direction of a ſkilful phyſician. He thought too, that many ſmall ſhocks might have been more proper than the few great ones which he gave; ſince, in an account from Scotland, a caſe was mentioned in which 200 ſhocks from a phial were given daily, and a perfect cure had been made *.

THAT there is an intimate connection between the ſtate of electricity in the air and the human body, is evident from ſeveral facts, particularly a very remarkable one related by the Abbé Mazeas, in a letter to Dr. Hales. He was electrifying a perſon who was ſubject to epileptic fits, by his apparatus to make obſervations upon the electricity of the common atmoſphere. At firſt this perſon bore the ſparks very well, but in two or three minutes the Abbé, perceiving his countenance to change, begged he would retire, leſt any accident ſhould happen; and he was no ſooner returned home, than his ſenſes failed him, and he was ſeized with a moſt violent fit. His convulſions were taken off with ſpirits of

* Phil. Tranſ. Vol. l. pt. ii. p. 481.

hartſhorn,

hartſhorn, but his reaſon did not return in an hour and an half. He went up and down the ſtairs like one who walks in his ſleep, without ſpeaking to, or knowing any perſon, ſettling his papers, taking ſnuff, and offering chairs to all who came in. When he was ſpoken to, he pronounced inarticulate words, which had no connection.

WHEN this poor man recovered his reaſon, he fell into another fit; and his friends told the Abbé, he was more affected with that diſtemper when it thundered than at any other time; and if it ever happened, which it rarely did, that he then eſcaped, his eyes, his countenance, and the confuſion of his expreſſions, ſufficiently demonſtrated the weakneſs of his reaſon.

THE next day, the Abbé learned from the perſon himſelf, that the fear of thunder was not the cauſe of his diſeaſe; but that, however, he found a fatal connection between that phenomenon and his diſtemper. He added, that when the fit ſeized him, he perceived a vapour riſing in his breaſt, with ſo much rapidity, that he loſt all his ſenſes before he could call for help*.

MR. WILSON cured a woman of a deafneſs of ſeventeen years ſtanding. He alſo obſerves, that ſhe had a very great cold when ſhe began to be electrified; but that the inflammation ceaſed the firſt time, and the cold was quite gone when the operation had been

* Phil. Tranſ. Vol. xlviii. pt. i. p. 383.

performed

performed again the ſecond day. But he acknowledges, that he had tried the ſame experiment upon ſix other deaf perſons without any ſucceſs *.

THE ſame perſon obſerves, that one gentleman, near ſeventy years old, could never be made to receive a ſhock except in his wriſts. He ſays that he himſelf could once have borne very great ſhocks without inconvenience, but that he could not bear them at the time that he wrote.

MEDICAL electricity is very much obliged to the labours and obſervations of Mr. Lovet, lay-clerk of the cathedral church at Worceſter, who has for many years been indefatigable in the application of electricity to a great variety of diſeaſes. His ſucceſs has been very conſiderable, and all the caſes he has publiſhed ſeem to be well authenticated.

ACCORDING to Mr. Lovet, electricity is almoſt a ſpecific in all caſes of violent pains, of however long continuance, in every part of the body; as in obſtinate head-achs, the ſciatica, the cramp, and diſorders reſembling the gout. He had no trials of the proper gout, but only on thoſe who were ſlightly attacked, and who received immediate relief.

THE tooth-ach, he ſays, is generally cured inſtantly, and he ſcarce ever remembered any one who complained of its raging a minute after the operation †.

* Wilſon's Eſſay, p. 207.

† Lovet's Eſſay, p. 112.

It has ſeldom failed, he ſays, to cure rigidities, or a waſting of the muſcles, and hyſterical diſorders, particularly if they be attended with coldneſs in the feet. According to him, it cures inflammations, it has ſtopped a mortification, cured a fiſtula lachrymalis, and diſperſed extravaſated blood *. He alſo ſays it has been of excellent uſe in bringing to a ſuppuration, or in diſperſing without ſuppuration, obſtinate ſwellings of various kinds, even thoſe that were ſcrophulous. In his hands it cured the falling ſickneſs, and ſeveral kinds of fits, though the patients had been ſubject to them for many years; and one cure he mentions of a hemiplegia †. Laſtly, he relates a well atteſted caſe, from Mr. Floyer, ſurgeon at Dorcheſter, of a complete cure of what ſeemed to be a *gutta ſerena*. The ſame Mr. Floyer, he alſo ſays, cured with it two young women of obſtructions, one of whom had taken medicines a year to no purpoſe ‡.

In the rheumatiſm, Mr. Lovet candidly confeſſes, it has failed; but he ſays it was ſeldom in the caſe of young perſons, if they were taken in time.

The manner in which electricity operated in theſe cures, Mr. Lovet imagined to be, by removing ſecret obſtructions, which are probably the cauſe of thoſe diſorders. In all his practice he never knew an inſtance of harm being done by it, and thinks that, in all the caſes in which it has done harm, the manner

* Lovet's Eſſay, p. 76. † Ibid. p. 101.
‡ Ibid. p. 119.

of

of adminiſtering it has been injudicious. In general, he thinks the ſhocks have been made too great. This he imagined to have been the caſe of the patient before mentioned of Dr. Hart, who was made more paralytic by electric ſhocks. Mr. Lovet adviſes to begin, in general, with ſimple electrification, eſpecially in hyſterical caſes; then to proceed to taking ſparks, and laſtly to giving moderate ſhocks, but hardly ever any that are violent, or painful.

The account of the application of electricity by Dr. Zetzel of Upſal, which may be ſeen in Mr. Lovet's treatiſe, agrees in the main with the reſult of his own practice; and where there is any difference between them, Mr. Lovet thinks there are evident marks of unfairneſs in the Swediſh account. And a ſubſequent account from Sweden mentions ſeveral cures being made in thoſe very caſes, in which Dr. Zetzel ſays that no relief was to be had from electricity.

The Rev. Mr. J. Weſley has followed Mr. Lovet in the ſame uſeful courſe of medical electricity, and recommends the uſe of it to his numerous followers, and to all people. Happy it is when an aſcendency over the minds of men is employed to purpoſes favourable to the increaſe of knowledge, and to the beſt intereſts of mankind. Mr. Weſley's account of cures performed by electricity agrees very well with that of Mr. Lovet, whom he often quotes. He adds, that he has ſcarce ever known an inſtance in which ſhocks all

over the body have failed to cure a quotidian or tertian ague *. He mentions cafes of blindnefs cured or relieved by it; and fays that he has known hearing given by it to a man that was born deaf †. He mentions cures in cafes of bruifes, running fores, the dropfy, gravel in the kidnies (caufing the patient to part with it) a palfy in the tongue, and laftly in the genuine confumption. But Mr. Boiffer fays it is of differvice in phthifical complaints ‡.

MR. WESLEY candidly fays, he has not known any inftance of the cure of an hemiplegia; and though many paralytics have been helped by electricity, he fcarcely thinks that any palfy of a year's ftanding has been thoroughly cured by it. He afferts, however, that he has never yet known any perfon, man, woman, or child, fick or well, who has found (what Mr. Wilfon fays, that fome perfons complained of) an unufual pain fome days after the fhock. Mr. Wefley had only known that the rheumatic pains, which were afterwards perfectly cured, had increafed on the firft or fecond application §.

MR. WESLEY directs the fame method of adminiftration with Mr. Lovet. In deep hyfterical cafes, he advifes that the patients be fimply electrified, fitting on cakes of rofin, at leaft half an hour morning and evening;

* Wefley's Defideratum, p. 3. † Ibid. p. 48.

‡ Carmichael Tentamen inaugurale medicum de Paralyfi, p. 34. ex Act. Upf.

§ Wefley's Defideratum, p. 50.

when,

when, after ſome time, ſmall ſparks may be taken from them, and afterwards ſhocks given to them, more or leſs ſtrong, as their diſorder requires; which, he ſays, has ſeldom failed of the deſired effect *.

THIS account of the medical uſe of electricity by Mr Lovet and Mr. Weſley is certainly liable to an objection, which will always lie againſt the accounts of thoſe perſons who, not being of the faculty, cannot be ſuppoſed capable of diſtinguiſhing with accuracy either the nature of the diſorders, or the conſequences of a ſeeming cure. But, on the other hand, this very circumſtance of their ignorance of the nature of diſorders, and conſequently of the beſt method of applying electricity to them, ſupplies the ſtrongeſt argument in favour of its innocence at leaſt. If in ſuch unſkilful hands it has produced ſo much good, and ſo little harm; how much more good, and how much leſs harm would it probably have produced in more ſkilful hands.

BUT whatever weight there be in this objection againſt the laſt mentioned writers, it certainly cannot be urged againſt Antonius de Haen, one of the moſt eminent phyſicians of the preſent age; who, after ſix years uninterrupted uſe of it, reckons it among the moſt valuable aſſiſtances of the medical art; and expreſsly ſays, that though it has often been applied in vain, it has often afforded relief

* Weſley's Deſideratum, p. 56.

where no other application would have been effectual. But I ſhall recite in a ſummary manner, from his *Ratio Medendi*, the reſult of all his obſervations on this ſubject.

WITH reſpect to partial palſies, in particular, he ſays, it never did the leaſt harm; that one or two perſons who had received no benefit from it in ſix intire months, were yet much relieved by perſevering in the uſe of it. That ſome perſons diſcontinuing it, after having received ſome benefit, relapſed again; but afterwards, by recurring to the uſe of electricity, recovered, though more ſlowly than before. Some perſons, he ſays, were relieved who had been paralytic one, three, ſix, nine, and twelve years, and ſome longer; but that in one or two of theſe caſes, the patients had received leſs relief, and more ſlowly than was uſual in recent caſes. In ſome caſes, he ſays, a moſt unexpected benefit had been found by thoſe who had been paralytic in their tongues, eyes, fingers, and other particular limbs. A paralyſis and trembling of the limbs, from whatever cauſe it aroſe, he ſays, never failed to be relieved by it; and he relates one inſtance of a perfect cure being performed in a remarkable caſe of this nature, after receiving ten ſhocks *.

DE HAEN's cuſtom was to apply the operation for half an hour together at leaſt. He ſeems to have uſed gentle ſhocks, and he joined to electricity, the uſe of other remedies,

* Ratio Medendi, Vol. i. p. 234, 199.

which,

which, however, would not have been effectual without it *.

St. Vitus's dance, he says, never failed to be cured by electricity †. He always observed it to promote a more copious discharge of the menses, and to relieve in cases of obstruction; but, for this reason, he advises that it be not administered to women with child. He found it of use in some cases of deafness, but it entirely failed in its application to a gutta serena, and to a strumous neck ‡.

Lastly, he relates a remarkable case, communicated to him by Mr. Velse at the Hague, of the cure of a mucous apoplexy §.

To the cases which have been mentioned occasionally, in which harm may be apprehended from electrification, may perhaps be added the venereal disease in which Mr. Veratti advises, that electrification be by all means avoided ‖.

I shall conclude this account of medical electricity with observing, that there are two general effects of electricity on the human body, of which, it should seem, that physicians might greatly avail themselves. These are, that it promotes insensible perspiration, and glandular secretion. The former is effected by simple electrification, and the latter

* Ratio Medendi, Vol. i. p. 233. † Ibid. p. 389.
‡ Ibid. Vol. ii. p. 200. § Ibid.
‖ Carmichael Tentamen, p. 34.

by taking ſparks from the glands, or the parts contiguous to them; on which it acts like a ſtimulus. Of the former, inſtances have been produced in the experiments of the Abbé Nollet, and a few have been given occaſionally of the latter.

To theſe I ſhall now add, that Linnæus obſerved, that when electric ſparks have been drawn from the ear, it has inſtantly promoted a more copious ſecretion of ear-wax; and that it has alſo been obſerved, that, when the eye, or the parts about the eye, have been electrified, the tears have flowed copiouſly. But the moſt remarkable caſe that I have met with, is, of its promoting the ſecretion of that matter which forms the hair; whereby hair has been actually reſtored to a part that had long been bald *.

HITHERTO electricity has been generally applied to the human body either in the method of drawing ſparks, as it is called, or of giving ſhocks But theſe operations are both violent, and though the ſtrong concuſſion may ſuit ſome caſes, it may be of diſſervice in others, where a moderate ſimple electrification might have been of ſervice.

THE great objection to this method is the tedioufneſs and expence of the application. But an electrical machine might be contrived to go by wind or water, and a

* Carmichael Tentamen, p. 33.

convenient

convenient room might be annexed to it; in which a floor might be raiſed upon electrics, and a perſon might ſit down, read, ſleep, or even walk about during the electrification. It were to be wiſhed, that ſome phyſician of underſtanding and ſpirit would provide himſelf with ſuch a machine and room. No harm could poſſibly be apprehended from electricity, applied in this gentle and inſenſible manner, and good effects are, at leaſt, poſſible, if not highly probable. It would certainly be more for the honour of the faculty, that the practice ſhould be introduced in this manner, than that it be left to ſome rich Valetudinarian, who may take it into his head, that ſuch an operation may be of ſervice to him.

SECTION XV.

MISCELLANEOUS EXPERIMENTS AND DISCOVERIES MADE WITHIN THIS PERIOD.

HAVING diſtributed into diſtinct ſections all the ſubjects, under which I had collected materials enow to form a ſeparate account; I have reſerved for the laſt place, thoſe ſmaller articles, which could neither with propriety be introduced under the former heads, nor were large enough to make a ſection themſelves.

IT has been a great controverſy among electricians, whether glaſs be permeable to the electric fluid. Mr. Wilſon appeared in favour of the permeability, and, in a paper read at the Royal Society, December the 6th, 1759, produced the following experiments to ſupport his opinion; notwithſtanding he, even afterwards, acknowledged, in a paper read at the Royal Society, November the 13th, 1760; that, in the Leyden experiment, Dr. Franklin had proved that the fluid did not go through the glaſs *.

HE took a very large pane of glaſs, a little warmed; and holding it upright by one edge, while the oppoſite edge reſted upon wax, he rubbed the middle part of the ſurface

* Phil. Tranſ. Vol. li. pt. ii. p. 896.

with

with his finger, and found both ſides electrified *plus* *.

UPON this I cannot help obſerving that it ought to be ſo on Dr. Franklin's principles. If one ſide be rubbed by the finger, it acquires from the finger ſome of the electric fluid. This, being ſpread on the glaſs as far as the rubbing extended, repels an equal quantity of that contained in the other ſide of the glaſs, and drives it out on that ſide, where it ſtands as an atmoſphere, ſo that both ſides are found *plus*. If the unrubbed ſide were in contact with a conductor communicating with the earth, the electric fluid would be carried away, and then that ſide would be left *apparently* in the natural ſtate. If the electric fluid found on the unrubbed ſide was really part of that which had been communicated by and from the finger, and ſo had actually *permeated* the glaſs, it might, when conducted away, be continually replaced by freſh permeating fluid communicated in the ſame manner: But if the effect is continually diminiſhing, while the ſuppoſed cauſe, repeated, continues the ſame, there ſeems reaſon to doubt the ſuppoſed relation between that cauſe and the effect. For it appears difficult to conceive how ſome electric fluid, having paſſed through a permeable body, ſhould make it more difficult for other particles of the ſame electric fluid to follow, till, at length, none could paſs at all.

* Phil. Tranſ. Vol. li. pt. i. p. 314.

MR. WILSON alſo ſays, that, holding the ſame pane of glaſs within two feet of the prime conductor, which was electrified *plus*, that part of the glaſs which was oppoſite to the conductor became electrified *minus* on both ſides; but, in a few minutes, the *minus* electricity diſappeared, and the *plus* continuing, diffuſed itſelf into the place of the other, ſo that now the whole was electrified *plus*.

THE experiment ſo far ſucceeding, induced him to make uſe of a leſs piece of glaſs, that the whole might be electrified *minus*. Theſe advances, he ſays, led him to obſerve the power of electrifying that ſmall piece of glaſs at different diſtances.

HE expoſed the ſame ſmall piece of glaſs to the prime conductor, at the diſtance of two feet, and obſerved a *minus* electricity at both ſurfaces.

As he moved the glaſs nearer, to a certain diſtance, it was more ſenſibly electrified *minus*; and after that, on moving it ſtill nearer, the *minus* appearance was leſs and leſs ſenſible; till it came within the diſtance of about one inch, and then it was electrified *plus* on both ſides.

THIS *plus* electricity in the glaſs, he found, might be changed to a *minus* again, by removing the glaſs, and holding it for a time at a greater diſtance; which he thought to be a proof of the repulſive power of that fluid *.

HAVING by him a pane of glaſs, one ſide of which was rough and the other ſmooth, he

* Phil. Tranſ. Vol. li. pt. i. p. 328.

rubbed

rubbed it ſlightly on one ſide; upon doing which, both ſides were electrified *minus*.

On this I muſt alſo take the liberty to obſerve that, as the electric fluid contained in glaſs in its natural ſtate, is kept equal in both ſides by the common repulſion; if the quantity in one ſide is diminiſhed, the fluid in the other ſide, being leſs repelled, retires inward, and leaves that ſurface alſo *minus*.

Slight changes, *plus* or *minus*, may be made in either ſurface, that have not ſtrength to act on the other ſide, by repulſion, or by abating repulſion, through the glaſs; and ſo *plus* electricity may be given to one ſurface, and *minus* to the other in ſome degree. Both ſides may alſo be made *plus*, and both *minus*, by rubbing, or by communication, without any neceſſity of ſuppoſing the glaſs *permeable*.

And yet it is probable that ſome glaſs, from having a greater mixture of non-electric matters in its compoſition, may be permeable, when cold, in ſome ſmall degree, as all glaſs is found to be when warmed.

Mr. Wilson treated the other ſide of this pane of glaſs in the ſame manner, after which the *minus* electricity was changed into a *plus* on both ſides.

Though Dr. Franklin was of opinion, that glaſs when cold is not permeable to electricity, he had made no experiments upon it when hot; but Mr. Kinnerſley, a friend of his, made one, which ſeemed to prove, that it was very differently affected in this reſpect, in the different ſtates of hot and cold. He found, that

that a coated Florence flaſk (made of very thin glaſs, and full of air bubbles) containing boiling water, could not be electrified. The electricity, he ſays, paſſed as readily through it as through metal. The charge of a three pint bottle went freely through it, without injuring the flaſk in the leaſt. When it became cold, he could charge it as before. This effect he attributed to the dilatation of the pores of glaſs by heat *.

ALL Mr. Wilſon's experiments to prove the permeability of glaſs were repeated by Mr. Bergman of Upſal; and, as he ſays, with ſucceſs †.

MR. ÆPINUS, however, was by no means ſatisfied with Mr. Wilſon's experiments concerning the permeability of glaſs; and yet he brings no other fact in anſwer to his arguments, but a very common one, which ſhows that a glaſs tube both receives and loſes its electricity very ſlowly; ſo that he only aſſerts a *difficulty*, and a *ſlowneſs* in the electric fluid paſſing through electric ſubſtances, as was mentioned before; and conſequently Mr. Wilſon ſeems to have an advantage in the controverſy: for, as he ſays, paſſing through, though ever ſo ſlowly, is a real paſſing through ‡.

MR. ÆPINUS has ſhown, by a curious experiment, that though a metallic conductor and a cork ball be both electrified poſitively,

* Phil. Tranſ. Vol. liii. pt. i. p. 85.
† Ibid. Vol. lii. pt. ii. p. 485.
‡ Ibid. Vol. liii. p. 443.

ſo

ſo as to repel one another; yet, that, if the ball be forcibly brought within two, three, or four lines of the conductor, it will be attracted by it; and that it will be repelled again, if it be forcibly puſhed beyond that limit of attraction. If the ball be confined to move within the ſame ſmall diſtance, a moderate electrification of the conductor will repel the ball to its utmoſt limit; but a ſtronger electrification of the conductor will cauſe it to be attracted. He, therefore, limits the general maxim, that bodies poſſeſſing the ſame kind of electricity repel one another; and aſſerts, that this will be the caſe, only when the quantity of electric fluid belonging to them both, as one body is greater, or leſs than that which is natural to them*. This experiment deſerves particular attention.

Signior Beccaria, who has contributed ſo largely to ſeveral former ſections in this period, furniſhes a few articles which well deſerve a place in this.

He thought it was evident, that the electric fluid tended to move in a right line, becauſe a longer ſpark may be taken in a direct line, from the end of a long conductor, than can be taken from the ſame place in any other direction. But he thought it was ſtill more evident, from obſerving, both in the air, and in vacuo; that, preſenting the finger, or a braſs ball, at a proper diſtance, and in a certain angle with the conductor (which experi-

* Æpini Tentamen, p. 146.

ence

ence will ſoon find) the electric ſpark will make an exact curve, to which the conductor produced will be a tangent: as if the electric matter was acted upon by two different forces, one its own acquired velocity, urging it forward in a right line; the other the attraction of the body preſented to it, which throws it out of the right line *.

In his obſervations on pointed bodies, he ſays, that two pointed bodies, equally ſharp, in their approach to an electrified conductor, will appear luminous only at half the diſtance at which one of them would have done †.

The ſame ingenious philoſopher reports a curious, but cruel experiment which he made on a live cock. He detached the belly of one of the muſcles from the thigh of the animal, leaving the extremities in their proper inſertions, and then diſcharging a ſhock through it. At the inſtant of the ſtroke, the leg was violently diſtended, and the muſcle greatly inflated; the motion beginning at the tendon, and the extenſion of it reſembling the opening of a lady's fan. No pricking with a pin could make it act ſo ſtrongly ‡.

I must not omit to mention, in this chapter of miſcellaneous experiments, what the Dutch writers have reported concerning the gymnotus, a fiſh peculiar to Surinam, which very much reſembles what naturaliſts relate concerning the torpedo. Mr. Muſchenbroeck

* Elettriciſmo artificiale, p. 56. † Ibid. p. 67.
‡ Lettere dell' elettriciſmo, p. 129.

ſays,

ſays, the gymnotus is poſſeſſed of a kind of natural electricity, but different from the common electricity, in that perſons who touch it in water are ſhocked, and ſtunned by it, ſo as to be in danger of drowning. The fiſh has been taken, and put into a veſſel; when experiments were made upon it at leiſure; and it was found, that it might be touched with all ſafety with a ſtick of ſealing-wax; but if it was touched with the naked finger, or with a piece of metal, and eſpecially a gold ring, held in the fingers, the arm was ſhocked as high as the elbow. If it was touched with the foot, the ſenſation reached as high as the knee, and the pain was as great as if the part had been ſtruck with ſomething hard. This kind of electricity is the ſame by night or by day, when the wind is in every direction, when the fiſh was put in veſſels of any materials, and whether it was in water or out of water. Every part of the body of the fiſh is capable of giving this ſhock, but more eſpecially the tail. The ſenſation is the ſtrongeſt when the fiſh is in motion, and it is tranſmitted to a great diſtance; ſo that if perſons in a ſhip happen to dip their fingers or feet in the ſea, when the fiſh is ſwimming at the diſtance of fifteen feet from them they are affected by it. Other fiſhes, put into the ſame veſſel with it, preſently died; but it is itſelf killed by the lobſter. The gymnotus is found in the upper part of the river of Surinam, particularly the

rocky part of it. It feeds upon all kinds of fiſh, and will even eat bread. This author propoſes as a query whether the ſenſation communicated by the torpedo does not depend upon a ſimilar electricity; ſince Monſieur Reaumur ſays, that when it is touched, the hand, arm, and ſhoulder are ſeized with a ſudden ſtupor, which laſts for ſome time; and is unlike any other ſenſation *.

THIS gymnotus, I ſuppoſe, is a different fiſh from the *Anguille tremblante, the trembling eel*, which is alſo a native of Surinam, and lives in marſhy places, from whence it cannot be drawn, except when it is intoxicated. It cannot be touched with the hand, or with a ſtick, without feeling a terrible ſtun, which reaches as high as the ſhoulder. If it be trod upon with ſhoes, the legs and thighs are affected in a ſimilar manner. Fourteen perſons joining hands, and the firſt of them touching it with a ſtick, they were all ſhocked violently. It is conjectured that this power of giving a ſhock reſides in two muſcles, which are particularly prominent and conſpicuous †.

IT is to be regretted, that none of the perſons who have made experiments on theſe fiſhes ſhould have endeavoured to aſcertain whether they were capable of exhibiting the phenomena of attraction and repulſion, or

* Muſchenbroeck's Introd. ad philoſoph. naturalem, No. 901—909.

† P. Fermin's Nat. Hiſt. of Surinam, p. 59.

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the appearance of electric light, as experiments of this kind are of principal consequence, and must have been very easy to make.

Mr. Hamilton, professor of Philosophy at the university of Dublin, made a curious experiment with a wire, five or six inches long, finely pointed at each end. To the middle of this wire he fitted a brass cap, which rested on the point of a needle communicating with the conductor. Half an inch at each extremity of this wire he bent, in opposite directions, perpendicular to the rest of the wire, and in the plane of the horizon. The consequence of electrifying this apparatus was, that the wire would turn round with very great velocity; moving, as he says, always in a direction contrary to that in which the electric fluid issues from its point, without having any conducting substance near it, except the air. He also observes, that if this wire were made to turn the contrary way, it would stop, and turn as before *.

The same experiment was also made by Mr. Kinnersley of Boston, with this addition, that he electrified the wire negatively; and observed, to his great surprize, that it still turned the same way. This he endeavoured to account for by supposing that, in the former case, the points, having more electricity than

* Phil. Transf. Vol. li. pt. ii. p. 905.

the air, were attracted by it; in the latter case, the air, having more than the points, was attracted by them *.

It may, by some, be thought that this pointed wire turning the same way, whether it be electrified negatively or positively, is a proof that the electric fluid issues out at the points in both cases alike, and by the reaction of the air is, together with the points, driven backwards; contrary to what ought to have been the case if the electric fluid had really issued out of the point in one case, and entered it in the other. But it will be found by experiment, that an eolipile, with its stem bent like the wire above mentioned, and suspended on its center of gravity by a fine thread, will move in the same direction, whether it be throwing steam out at the orifice; or, after it is exhausted, and cooling, it be drawing the air or water in.

With respect to the power of points, it has been observed by Mr. Villette of Liege, that a needle, concealed in a glass tube, which projected an inch beyond it, takes a stronger spark from a prime conductor than a man's finger; also that when the points of needles are covered with tallow, bees-wax, sulphur, &c. they take peculiarly strong sparks. He adds, that, when sulphur is used, and the sparks are taken obliquely, they are sometimes of a beautiful citron colour †.

* Phil Transf. Vol. liii. pt. i. p. 86.
† Nollet's Letters, Vol. iii. p. 212.

Mr.

Mr. Lullin has made an additional observation to Monsieur du Fay's, concerning the different manner in which conducting and non-conducting substances are affected, when they are exposed to the dew. He says, that if a plate of glass be extended upon silken threads, and exposed to the open air all night, and a plate of metal, less than the glass, be laid upon it, in the morning, the metal will be dry, and likewise the glass, on both sides, exactly under the metal; but that the edges of the glass, where the metal did not reach, will be wet on both sides *.

I shall close this section of miscellaneous articles, and the whole history of electricity, with a succinct account of some of the chief particulars in which the analogy between electricity and magnetism consists; very nearly as it was drawn up, in an abridgment of Mr. Æpinus, and communicated to me for this purpose by Dr. Price.

1. As a rod of iron held near a magnet will have several successive poles; so will a glass tube touched by an excited tube have a succession of positive and negative parts.

2. Bodies positively and negatively electrical, when in contact, will unite to one another; as will magnets, when they are laid with their opposite poles to one another.

* Nollet's Letters, Vol. iii. p. 54.

3. Glass

3. GLASS is a ſubſtance of a nature ſimilar to hardened ſteel. The poſitive and negative ſides of the former anſwer to the attracting and repelling ends of the latter, when magnetical.

4. As it is difficult to move the electric fluid in the pores of the former; ſo, likewiſe, it is difficult to move the magnetic fluid in the pores of the latter.

5. As there can be no condenſation of the electric fluid in the former, without a rarefaction; ſo, in the latter, if there be a condenſation, or poſitive magnetiſm in one end of a bar, there muſt be an evacuation, or negative magnetiſm in the other end.

6. STEEL correſponds to electrics per ſe, and iron in ſome meaſure, to conductors of electricity.

7. STEEL is leſs ſuſceptible of the magnetic virtue, but when it has acquired it, it retains it more ſtrongly than iron; juſt as electrics per ſe will not ſo eaſily receive the electric fluid, but, when it is forced into them, will retain it more ſtrongly than conductors.

8. MR. ÆPINUS adds, and reckons it one of his diſcoveries, that an electrified body does not act on other bodies, except they are themſelves electrified; juſt as a magnet will not act on any other ſubſtances, except they are themſelves poſſeſſed of the magnetic virtue. So that an electrified body attracts and repels another body, only in conſequence of rendering it firſt of all electrical; as a magnet attracts iron,

iron, only in consequence of, first of all making it a magnet.

9. Mr. Canton has also found, that if the tourmalin be cut into several pieces, each piece will have a positive and negative side, just as the pieces of a broken magnet would have.

Thus far, says Dr. Price, there is an analogy, and, in some instances, a striking one, between magnetism and electricity, upon the supposition that the cause of magnetism is a fluid. But there is no magnetic substance which answers perfectly to the conductors of electricity. There is no afflux or efflux of the magnetical fluid ever visible. The equilibrium in a magnet cannot be instantaneously restored, by forming a communication between the opposite ends with iron, as it may in charged glass. Nor are there any substances positively or negatively magnetical only, as there are bodies which are positively or negatively electrical only.

END OF THE FIRST VOLUME.

Plate I.

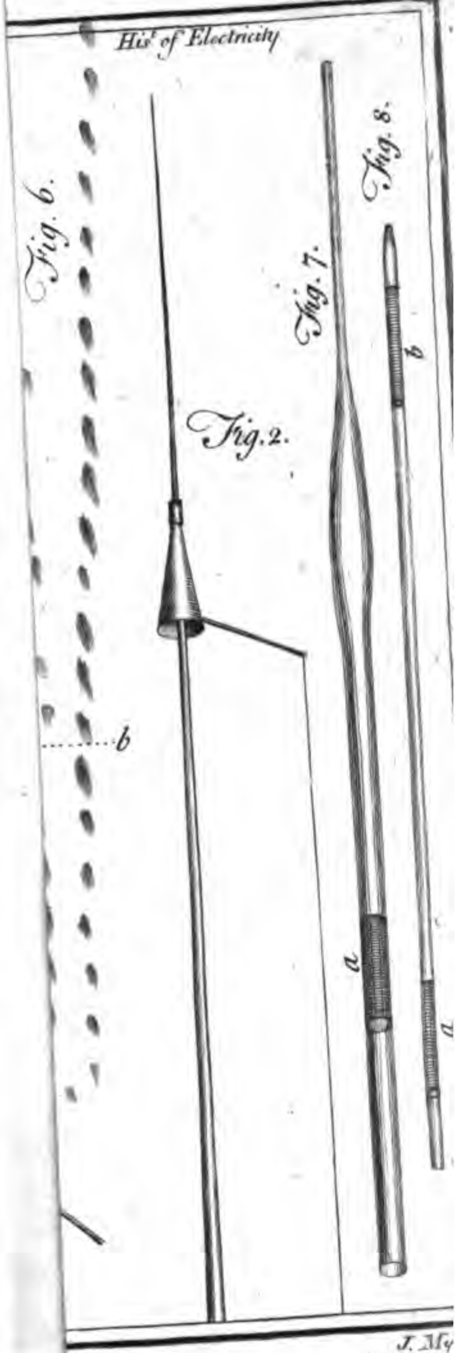
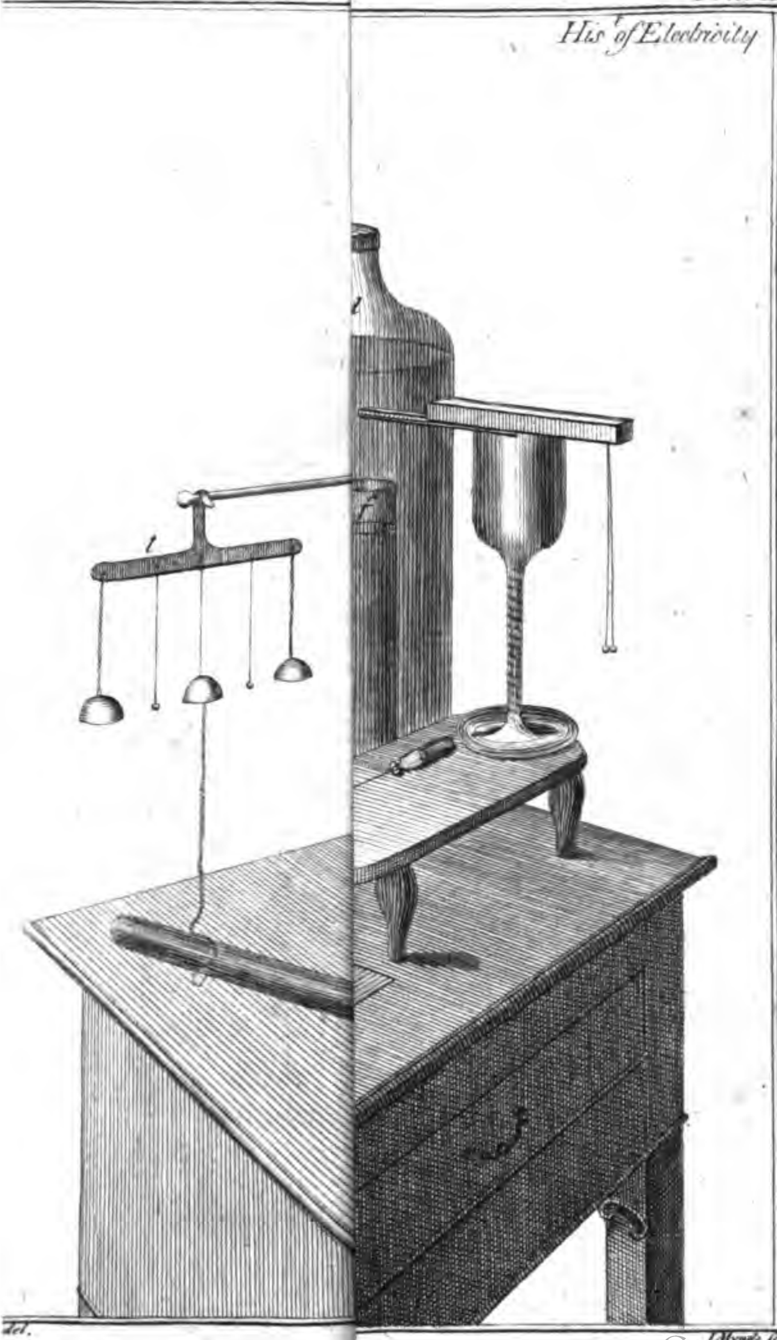


Plate II.

His^t of Electricity



del.

J. Mynde sc.

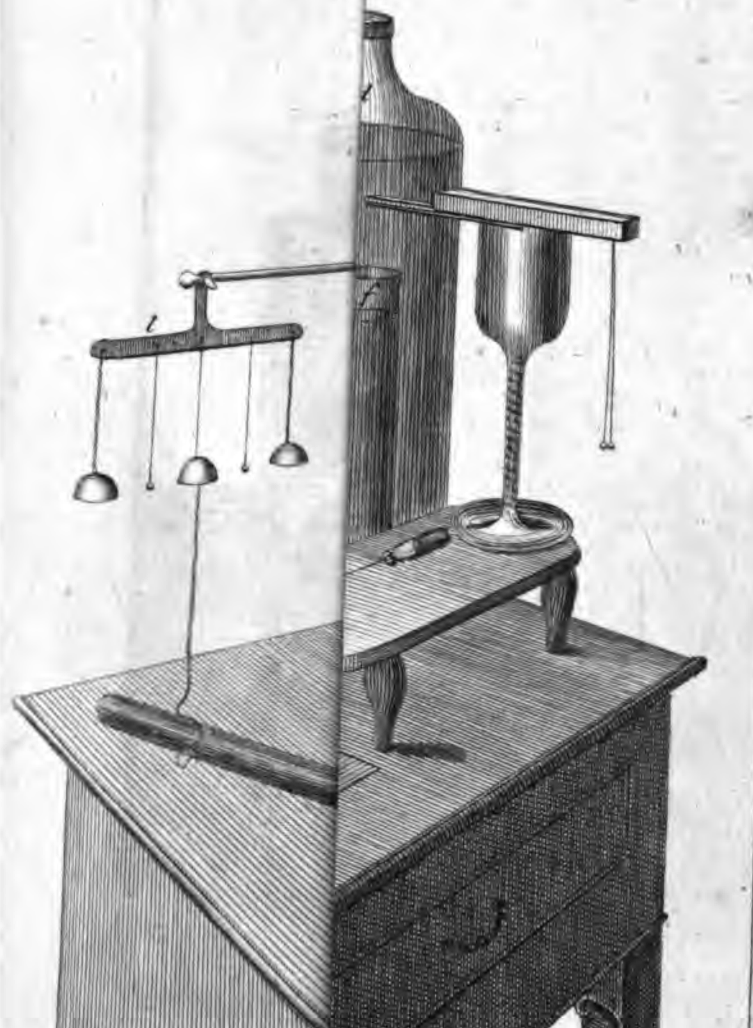

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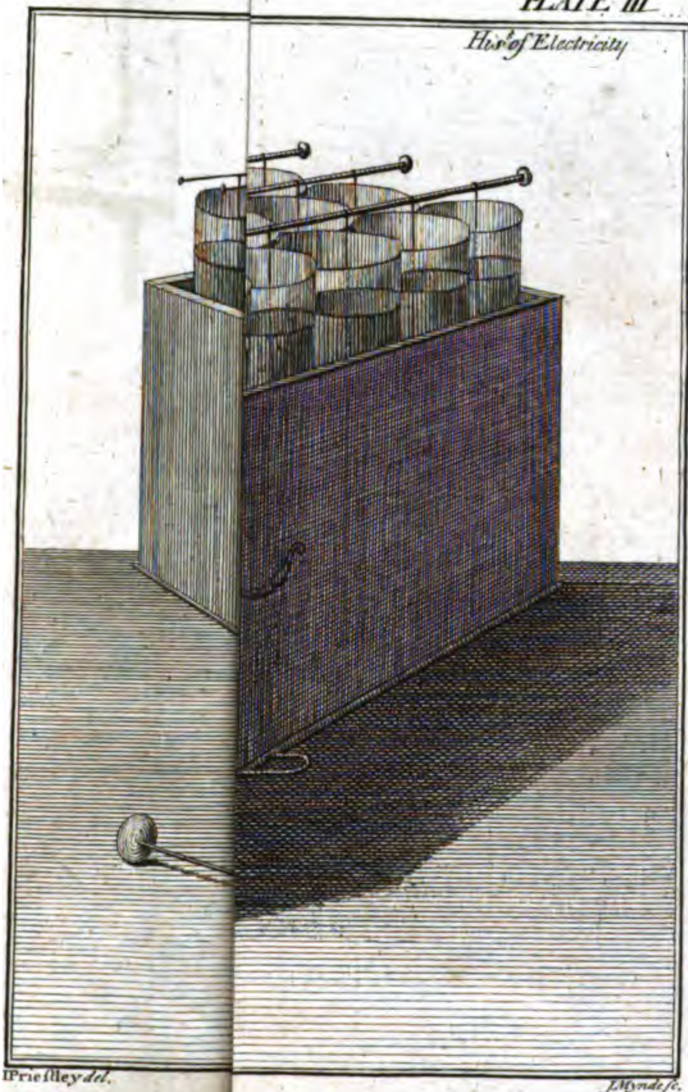
PLATE III

Hist. of Electricity



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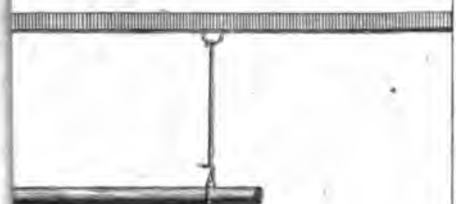

Fig. 1.

Fig. 2.